SHRI CHHATRAPATI SHIVAJI COLLEGE OMERGA

Notes for Organic Chemistry
M.Sc. First Year
First Semester

Dept of Chemistry

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UNIT – I   NATURE OF BONDING IN ORGANIC MOLECULES

Structure

1.0 INTRODUCTION

Since the ancient time's people were aware of vegetation, animals and living beings. The basic concept of Organic Chemistry is based on the above ideas. The vegetation, animals and living beings are nothing but organic origin. Every item after burning is converted into ‒Carbon‖ and truly speaking Organic Chemistry can be called as **Carbon Chemistry**. The beautiful lady, handsome man and healthy plants and animals are known to be healthy carbon contents.

The carbon comes from various sources, like vegetables, plants, animals etc. The human beings consume all types of vegetables and animal products. What are these products? How they are formed, is also a chemical phenomenon. The plants give various types of plant hormones, vitamins, terpines, anthocyanin and flavons, various fatty acids, essential oils, medicinal and aromatic compounds, fibers etc. Here the ‒C to C' linkages give these above compounds. The ‒C' may be linked by single bond (C-C) or by double, triple or multiple bonds. Plants manufacture above compounds in presence of sunlight, water and ofcourse minerals from earth. The linkages in **Carbon Chemistry** are called bonding and the bonding is responsible for various organic products.

1.1 OBJECTIVES

To describe the various aspects of this Unit in studying the growth and development of organic products and to appraise growth, the identification, analysis and development of various products are with their structural mechanism.

1.2 NATURE OF BONDING IN ORGANIC MOLECULES

Kossel & Lewis (1916) gave the ‗Electronic Theory of Bonding' to explain the formation of bonds or union between atoms, based on ‗Bohr's Atomic Model'. Where atom consist of a central positively charged nucleus, with neutrons and protons, having unit mass and the nucleus surrounded by the electrons, if the desired number of electrons (usually on octat)is not present in the last orbit it can be obtained by combining or losing or sharing electrons among themselves. The saturated outer orbit results in inert gases, which enter tain no chemical reaction.

The different modes of bond formation arise as a result of different manners, in which electron distribution occurs between the combining atoms to attain the stable inert gas electronic configuration. The bonding thus established is of three types:

• Ionic-bonding

• Co-valent bonding

• Co-ordinate-co-valent bonding or co-ordinate bonding.

Organic compounds are covalent compounds According to the modern VBT, concept, a covalent bond is formed between two atoms if there is an overlapping of an atomic orbital of one atom with an atomic orbital of another atom. For an effective overlap, it is necessary that two atomic

orbitals of the two different atoms must be half filled and approach each other in proper direction. The resultant orbital after overlapping is known as molecular orbital and has two electrons with opposite spins. The effective overlapping is possible by two ways :

(i) **End to end overlapping :** This type of overlapping is possible between s-s, s-p and p-p atomic orbitals. The molecular bond formed is termed as sigma (σ) bond.

(ii) **Sidewise or parallel or lateral overlapping :** Such overlapping is possible between p-p atomic orbitals. The molecular bond formed is termed as pi (π) bond.

Sigma bond is stronger than π-bond. The electrons in the π-bond are loosely held. The bond is easily broken and is more reactive than sigma bond. The amount of energy released during overlapping indicates the strength of the bond. Greater will be the strength of bond if higher energy is released during overlapping. Energy released during sigma bond formation is always more than the π-bond because of greater overlapping in the former. The valency of the atom depends on the number of sigma bonds formed or sigma and π-bond formed.

Tetravalency of carbon (Hybridization) :

The electronic configuration of carbon in ground sate is $1s^2 2s^2 2p_x^1 2p_y^1 2p_2^0$. Two p-orbitals are half filled and, therefore, carbon is expected to show a valency of two. But in all organic molecules, the carbon atom has a valency of four. It is, therefore, believed that under the conditions of bond formation, the 2s paired orbital gets unpaired and one electron is promoted to the vacant 2pz orbital. Thus, in excited state the

carbon has the electronic configuration $1s^2 2S^1 2p_y^1 2p_y^1 2p_z^1$, i.e. it has four half filled orbitals which can be available for overlapping. Under this conditions, it can form four bonds with other atmos. This explains the tetravelency of carbon.
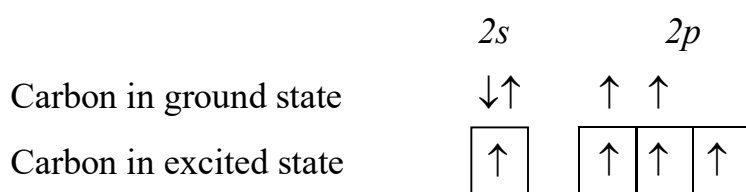

Carbon in ground state

Carbon in excited state

Fig 1.   Available for bond formation

To have four identical C – H bonds, carbon must contribute a set of four equivalent orbitals. Thsi is possible if one 2s and the three 2 p-orbitals in the excited state mix together to form four equivalent orbitals. The process of mixing atomic orbitals to form a set of new equivalent orbitals is termed as hybridization.

There are three types fo hybridisation encountered in carbonation. These are sp^3, sp^2 and sp hybridization.

(i)   **sp^3 shybridization :** sp^3 hybridization occurs when one s-orbital and three p-orbitals mix together to form four equivalent hybrid orbitals directed towards the corners of a regular tetrahedron.

(ii)   **sp^2 hybridization :** sp^2 hybridization occurs when one s-orbital and two p-orbitals mix together to form three equivalent hybrid orbitals directed towards the corners of an equilateral triangle, i.e., the three hybrid orbitals lie in the same plane. The third $2p_2$-orbital is left unhybridized. This orbital is oriented along an axis perpendicular to the

plane of hybrid sp^2-orbitals. Each sp^2 hybrid orbital and 2p$_z$-unhybridized orbital contains one electron.
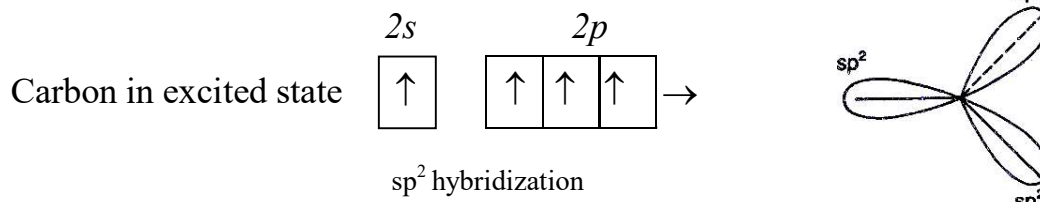
Carbon in excited state

2s   *2p*

| ↑ | | ↑ | ↑ | ↑ | → |

sp^2 hybridization

Fig. -3 Orientation of three sp^2 hybrid orbitals

Whenever carbon is bonded to three other atoms or groups, it always uses sp^2 hybrid orbitals and a p$_z$ orbital to form its bonds. The best example is ethylene molecule.

In ethylene molecule, each carbon atom is attached to three other atoms. Each carbon atom is sp^2 hydridized. One sp^2 hybrid orbital of one carbon atom overlaps coaxially with that of another carbon atom to form a sigma bond. The remaining sp^2 hybrid orbitals of two carbon atoms overlap with 1s-orbital of different hydrogen atoms and form four sigma bonds. The

(iii) **sp-hyridization :** This hybridization occurs when one s-orbital and other two 2p-orbitals are left unhybridized. Each sp-orbital and unhybridized p-orbital contain an unpaired electron. Each hybrid orbital possesses same energy and shape. two sp-hybrid orbitals lie in a straight line, i.e., the angle between them is 180°. The unhybridized orbitals are at right angles to the line of sp-hybrid orbitals.
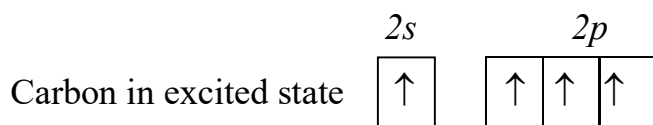
Carbon in excited state
2s *2p*

| ↑ | | ↑ | ↑ | ↑ |

Whenever a carbon atom is bonded to two other atoms or groups, it always uses sp-hybrid orbitals and two 2p-unhybridized orbitals to form its bonds. The best example is the acctylene molecule.

The three types of hybridization of carbon can, thus, be summarised in the following manner.

Type	Geometry	Bond angle	Number of unhybridized p-orbitals	% s-character	% p-character
sp^3	Tetrahedral	109°28' (109.5°)	0	25.0	75.0
sp^2	Trigonal planar	120°	1	33.3	66.6
sp	Linear	180°	2	50.0	50.0

Relative sizes of sp, sp^2 and sp^3 orbitals : s-orbital character in the three hybrid orbitals varies in the following manner –

$$sp > sp^2 > sp^3$$

Since s-orbitals are close to the nucleus than p-orbitals, it is, thus, expected that greater the s-character of the hybrid orbital the smaller is its size. Therefore, the order of the size of the three hybrid orbitals is :

$$sp^3 > sp^2 > sp$$

On the basis of the sizes, sp-orbital forms shortest and sp^3-orbital longest bonds with other atoms.

Molecular Orbital Method : LCAO Treatment :

The molecular orbital (MO) approach for understanding chemical bonding envisages the set of electronic orbitals belonging to the molecule as a whole. Like an isolated atom, a molecule is assumed to have orbitals associated with it. The only difference is that after the bond formation, the valence electrons of the constituent atoms occupy a new set of orbitals known as molecular orbitals. The Pauli exclusion principle is applied to the MO's in the same way as it is applied to the AO's. In other words, an MO cannot accommodate more than two electrons and these paired electrons must have opposite spins.

Molecular orbitals have been represented mathematically by an approximation known as Linear Combination of Atomic Orbitals (LCAO). In LCAO the combination of a given number of AO's gives rise to an equal number of MO's of different energies. Half of these MO's which are associated with lower energies than the AO's are filled with electrons pairs, while the remaining MO's of higher energies (than the AO's) are unoccupied in the ground state of the molecule. The former are known as bonding orbitals and the latter as antibonding orbitals. In case of radicals, carbonium ions and carbanions, one (or more) of molecular orbitals may possess the same energy as that of the atomic orbital, and such orbitals are said to be nonbonding orbitals.

Let us, for instance, consider the linear combination of AO wave functions of two atoms R and S forming a molecule RS. This can be done either by addition or subtraction of the two wave functions under consideration.

$$\Psi = \varphi_R + \lambda\varphi_S$$
$$\Psi^1 = \varphi_R - \lambda\varphi_S$$

Here Ψ and Ψ^1 are the MO wave functions and are obtained by combination (addition or subtraction) of AO wave functions φ_R and φ_S, λ representing the ionic character of the bond between R and S. The value of λ is unity when R is equal to S.

Since Ψ^2 is a measure of the electron charge density in a given volume element, the charge densities between the two atoms in the two MO's will be given by –

$$\Psi^2 = (\varphi_R + \lambda\varphi_S)^2 = \varphi_R{}^2 + \lambda^2\varphi s^2 + \lambda\ \varphi_R\varphi_S$$
$$\Psi^2 = (\varphi_R - \lambda\varphi_S)^2 = \varphi_R{}^2 + \lambda^2\ \varphi s^2 + 2\lambda\ \varphi_R\varphi_S$$

The term $2\lambda\varphi_R\varphi_S$ will, therefore, determine the energy difference between the two MO's. It follows that the charge density between the bonded atoms in the MO, Ψ, will be more than that between the two nonbonded atoms by the amount $2\lambda\varphi_R\varphi_S$. Similarly, the charge density between the bonded atoms in the MO, Ψ^1, will be less than that between the two non-bonded atoms by $2\ \gamma\ \varphi_S$. The MO Ψ is, therefore, called bonding orbital since in this orbital the probability of findings the two electrons along the molecular axis will be maximum. On the other hand,

the probability of finding the two electrons along the molecular axis in the MO, Ψ, will be minimum and it is, therefore, called antibonding orbital. The bonding orbital is associated with lower energy as compared to any of the AO's, and is designated σ orbital and the antibonding orbital, associated with higher energy than any of the two AO's, is desinated by σ*. It remains unfilled in the ground state of the molecule. It may be noted that splitting of the bonding and antibonding MO's with respect to the atomic energy level is not equal as interelectronic repulsion between the two electrons in the bonding MO raises its energy to some extent, although there is an overall energy decrease, i.e., increase in stability. Fig. depicts the LCAO of two hydrogen 1s AO's resulting in one bonding and one antibonding MO.

Fig.6 shows the relative energies of the AO's and MO's of hydrogen. It must be remembered that σ orbital is cylindrically symmetrical about the internuclear axis of the two atoms and has no nodal plane, i.e., the electron density is the highest along the internuclear axis.
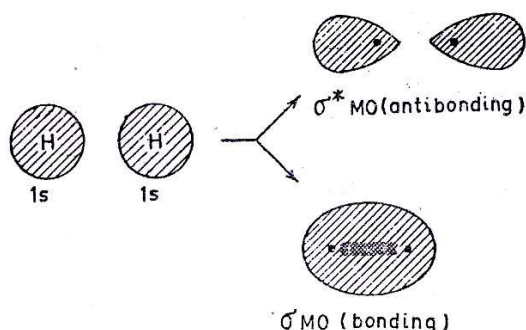

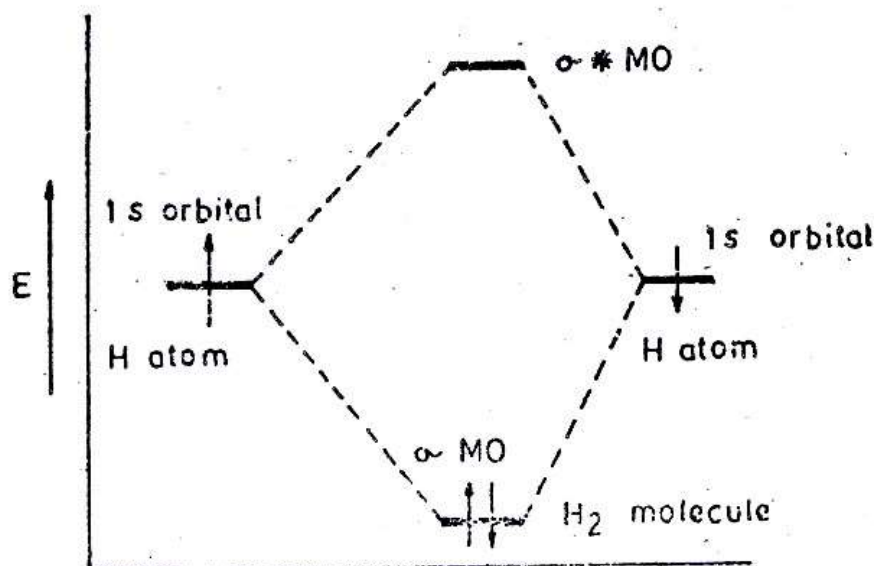**Fig.5 : LCAO of two 1s atomic orbitals**

Fig. 6: Relative energies of atomic (s) and molecular orbitlas (σ) of hydrogen

Thus there are two electrons of paired spines in the ground state of the hydrogen molecule. The energy of this system is at a minimum when the separation between the two nuclei is 0.74 Å, a distance that represents the bond length. The situation may be illustrated by plotting the energy of two hydrogen atoms as a function of distance (r), between the nuclei when the electrons are in bonding and antibonding orbitals (Fig.). As we know that in a system which is less energetic (more stable), the depth of the potential well represents the strength of the bond. Antibonding orbitals tend to push the nuclei apart.
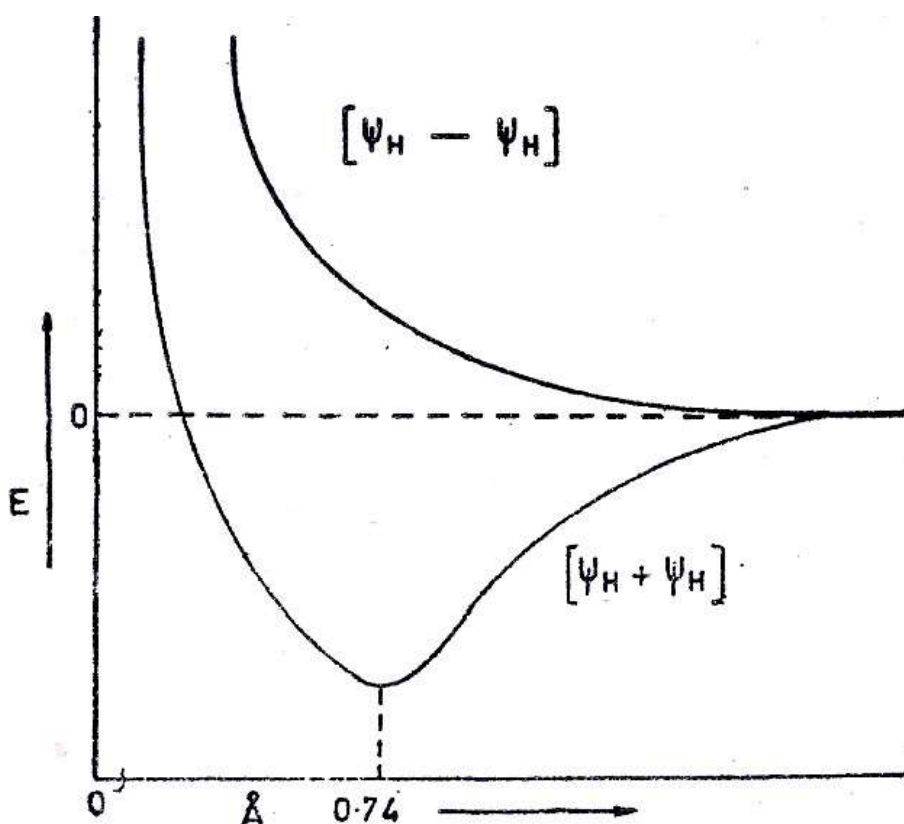
Fig.7 Potential energy curves for the formation of σ and σ* bonds between two hydrogen atoms.

1.2.1 Delocalized Chemical Bonding

As we have seen in the introduction, the compounds contain one or more bonding orbital that are not restricted to two atoms but that are spread out over three or more such bonding is said to be delocalized. There are a number of compounds for which it is possible to write more than one Lewis structures, differing only in the relative position of electrons. However, none of these structures conforms to all the observed properties of these substances. For instance, following three Lewis structures can be written for the carbonate anion.
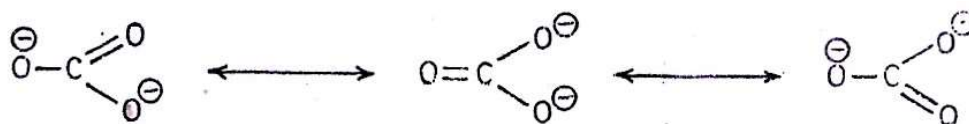
A perusal of these structures reveals that this anion has two carbon-oxygen single bonds and one carbon-oxygen double bond but neither of these predictions is consistent with the observation that all the C-O bonds in carbonate are of equal length (1.30Å). The concept of resonance was introduced to explain the limitations of the classical Lewis structures. According to this theory a molecule, for which more than one Lewis structures (differing only in the relative position of electrons) can be written, is conceived to have some fixed structure which may be a composite of all the possible Lewis structures. By composite structure we do not mean that the real molecule has one structure at one time and other structure(s) at the other time nor do we mean that some molecules have one structure and other molecules have others structure(s). In other words, the actual molecule is considered to be a hybrid or mesomer (G. between the parts) of all the possible Lewis structures which are referred to as contributing or canonical forms. One of the important assumptions of this theory is that the contributing or canonical forms have no real existence.

To depict the situation of resonance a double headed arrow ($\leftrightarrow$) is placed between each pair of the contributing forms. It is important to note that the double headed arrow does not signify the oscillation of molecule from one Lewis structure to another. In fact, the word resonance does not mean the mixing of formal structures and, therefore, a less confusion term for this phenomenon-π-electron delocalization-has been coined.

Several analogies have been drawn to understand the meaning of the term resonance hybrid. According to one analogy advanced by Wheland, a mule is hybrid of horse and donkey but it does not mean that some mules are horses and some are donkeys nor does it mean that some mules are horses and some are donkeys nor does it mean that a mule is a donkey part of the time and a horse part of the time. Roberts questioned the validity of this analogy as it had a serious drawback, i.e., horse and donkey are real species which Wheland compared with the contributing forms having no real existence, and are merely imaginary structures. So he proposed that an ideal analogy would be the description of a real animal in terms of some mythological creatures. Thus a closer analogy is to describe a rhinoceros as a sort of hybrid of a dragon and a unicorn which are purely mythological animals having no real existence. A person who has never seen a rhinoceros (as is really the case with a molecule capable of having resonance forms) but has some idea of the above mentioned imaginary animals (resonance forms) gets a good mental picture of the former.

An important example of resonance is that of benzene, which can be considered to be hybrid of two Kekule, and three Dewar forms with the latter contributing only little. The real structure of benzene molecule cannot be represented by any of these formulations, as all the carbon-carbon lengths are equal (1.39Å). This value is somewhat intermediate between carbon-carbon single bond (1.54Å) and carbon-carbon double bond (1.34Å).
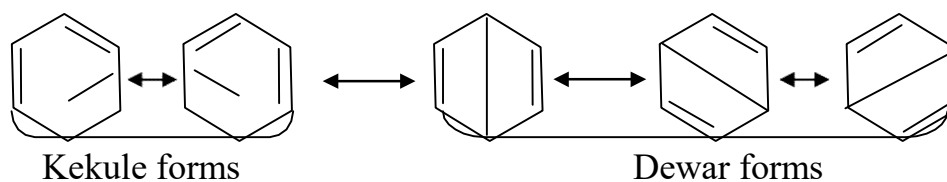
Kekule forms   Dewar forms

Fig. 8

Further, benzene resists addition reactions and is a highly stable molecule. The above structures on the other hand show it to be a highly unsaturated compound.

According to valence-bond method the concept of real structure as the weighted average of various possible contributing forms, with localized bonds, is called resonance.

The general method for solving the wave equation for compound containing localized and delocalized bonds is valence bond method and molecular orbital method. In the valence bond method several **Lewis structures** (canonical form) are drawn and the molecule is taken to be a weighted average of them.

$$\psi = C_1 \psi_1 \quad + \quad C_2 \quad \psi_2 \quad + \text{-------- (1)}$$

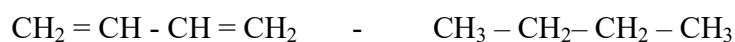Each ψ represents one of these structures. This representation of a real structure as a weighted average of two or more canonical forms is called resonance. The difference in energy between the actual molecule and the **Lewis structure** of lower energy is called the resonance energy. The shorter single bond provides evidences for resonance. The shortening can also be explained by hybridization changes e.g. ‖butadiene‖ is planar as shows that there is some delocalization. Similar delocalization is found in other conjugated system (e.g. – C = C – C = O & C = C – C = N).

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The delocalized chemical bonding is shown by benzene and its derivative, like anthracene, naphthalene. Simple examples are:

$$CH_2 = CHCH_2 - CH_3 \quad - \quad CH_3 - CH_2 - CH_2 - CH_3$$

Butene-1   **η -Butane**

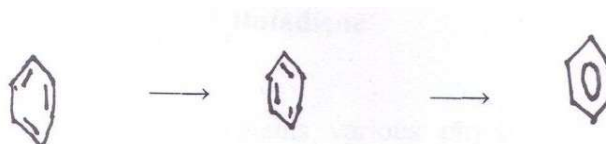$$CH_2 = CH - CH = CH_2 \quad - \quad CH_3 - CH_2 - CH_2 - CH_3$$
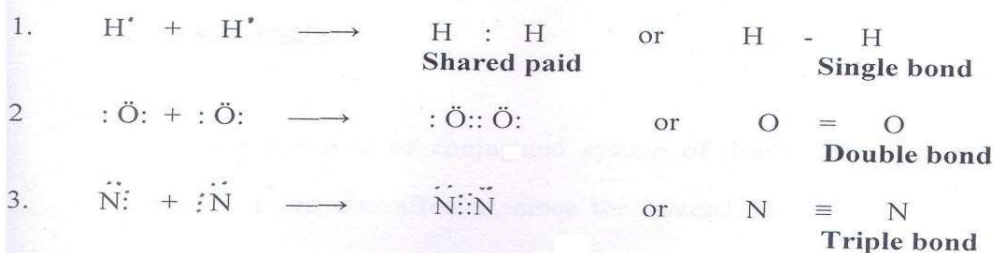
1, 3, Butadiene   **η-Butane**

This type of difference is observed in all compounds conferring conjugated system of double bond and does not exist in comparable compounds with unconjugated system of double bonds. The difference is still greater in aromatic compounds e.g. 36 k cal/mole in benzene.

Delocalized Bonds

It is known that a covalent bond is formed as a result of overlapping of atomic orbital of the combining atoms giving a molecular orbital. Thus alternate single and double

4.   :Ö: + :S: $\longrightarrow$:S::S: or   O = S:

$\rightarrow$ l One pair
Co-ordinate bond

O = S: + :Ö: $\longrightarrow$ O = S : Ö: or   O = S $\longrightarrow$ O

Donar   **Acceptor**   **Sulpher Dioxide**
Semipolar double bond

5. $CH_2 = CH - CH = CH_2$ $CH_2 = CH - CH = O$

                        1, 3 Butadiene   **Acraldehyde**

bond in a molecule is called conjugation. When atoms are free with electrons is separated from a multiple bond by a single bond certain interaction take place affecting the nature of the bonds, such interactions are generally known as conjugated multiple bonds.

This conjugation explains various physical constants and also chemical properties of the molecules exhibiting the phenomenon.

- **Heat of Hydrogenation**

The HOH (Heat of Hydrogenation) of an Olefine e.g. Butene -1 containing double bond is 30.3 K cal/mol. So it is expected that the heat of Hydrogenation of 1, 3 Butadiene (containing Two Double Bonds) must be 2 X 30.3 = 60.6 K cal/mol but measured value is found to 57.1 Kcal/mol is less by 60.6 – 57.1 = 2.9 K cal/mol.
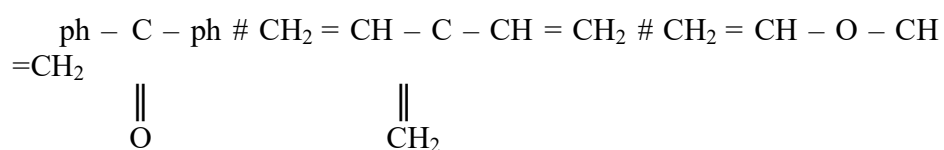
- **Bond Lengths**

The Presence of conjugated system of double bonds, normal bond distances are also affected, since the interaction causes the molecule to undergo the phenomenon of resonance, with the result of C - C bond acquires some character of C = C bond and vice versa e.g.

<div align="center">

| 1, 3 Butadiene – C – C bond length | C = C bond length |
</div>

$$1, 3 \text{ Butadiene} - C - C \text{ bond length} \qquad C = C \text{ bond length}$$

Calculated – 1.54 A˚   1.34 A˚

Observed - 1.46 A˚   1.39 A˚

Benzene – Calculated – 1.54 A˚   1.34 A˚

Observed - 1.39 A˚   1.39 A˚

These are the examples of explanation of conjugated system e.g. addition to conjugate olefines, resonance and molecular orbital theory like Butadiene.

1.2.2 Cross Conjugation

Three groups are present in this cross conjugation, two of which are not conjugated with each other, although each is conjugated with the third e.g.

$$ph - C - ph \# CH_2 = CH - C - CH = CH_2 \# CH_2 = CH - O - CH = CH_2$$
$$\quad\quad\; \| \quad\quad\quad\quad\quad\quad \| $$
$$\quad\quad\; O \quad\quad\quad\quad\quad\quad CH_2$$

- **Resonance**

It is phenomenon in which two or more structures involving identical position of atoms can be written for a particular compound. The canonical structures of a system may be defined as many set of valency structures which are sufficient to define all possible electrons' distribution fin 9. The _Resonance Hybrid' Structure as the actual structure of all different possible structures that can be written for the molecule

without changing the relative position of its atoms and without violating the rules of covalence maxima for the atoms.

Hybrid   **R.E. 36 K cal/mol**
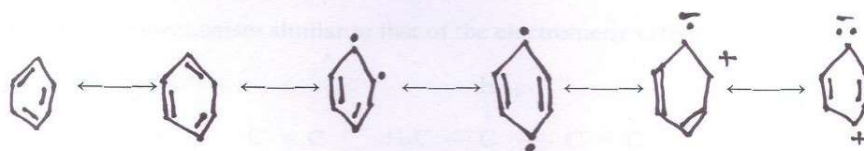
Necessary conditions for Resonance

Fig 10

For representing a resonance hybrid only the major contributing forms are used. The nucleus remains in same relative position and differ in electron distribution and all structures must have same number of paired and unpaired electrons. Non-polar structures are more stable than the dipolar, unless one atom is electropositive. More the number of co-valent bonds in a resonating structure more will be its stability. The difference in energy between the hybrid and the stable structures is referred to as the resonance energy of a molecule.

The effect of resonance is seem in the case of dipole moment, bond length, strength of acid-base and conjugated addition to diene.

1.2.3 Hyper-conjugation

In alkenes, the electron release due to the presence of the system H – C – C = C is known as **Hyper Conjugation**. More the number of C – H bonds attached to the unsaturated system more will be the possibility of electron release by this mechanism. The electron release will be greater in methyl, less in ethyl and isopropyl and essentially Zero in tert butyl group. –Baker and Nathan suggested that alkyl groups with atleast one H atom on the α - Carbon atom when attached to an unsaturated C atom are able to release electron by a mechanism similar to that of the electromeric effect.

$$H - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - C = C \qquad\qquad H_3C - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - C = C$$
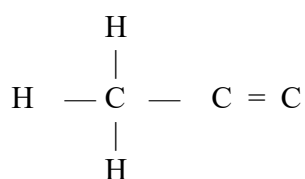
Methyl compound containing   **Ethyl compound containing**
3 H-C hyper conjugated bonds.   **H-C hyper conjugated bonds.**

$$H_3C - \underset{\underset{CH_3}{|}}{\overset{\overset{H}{|}}{C}} - C = C \qquad\qquad H_3C - \underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}} - C = C$$
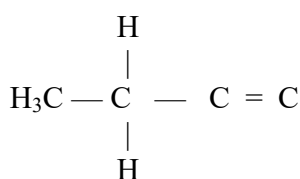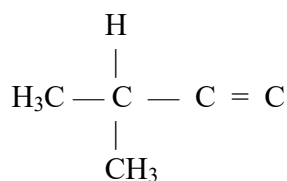
Iro-propyl compound containing   **Tert-butyl compound containing**
1H-C hyper conjugated bond.   **9 H-C hyper conjugated bonds.**

Baker & Nathan in 1935 introduced hyper conjugation. If the group-X is capable of withdrawing electron (C is – 1, – NO_2 gr.) from the Benzene ring. $O_2N \leftarrow C$ reaction shows up while the opposite group speeds it up.

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1.3   BONDING IN FULLERENES

Fullerenes have created great excitement in the organic chemistry world and in 1991 it was reported to possess remarkable properties of super conductors, resistance free conductivity at room temperature also.

X-ray shows that _C' atoms are arranged in a layer is a continuous network of planner, hexagonal rings, the Carbon atoms within a layer are held by weak forces and slip over one another. Newly discovered (1985), allotrope of carbon is **Buck Minster Fullerene** named for two designer of the Geodesic donee, unlike diamond and graphite, whose molecules go on & on, the fullerene has definite formula $C_6 0$. In Fullerenes, there is a room inside the hollow balls for metal.
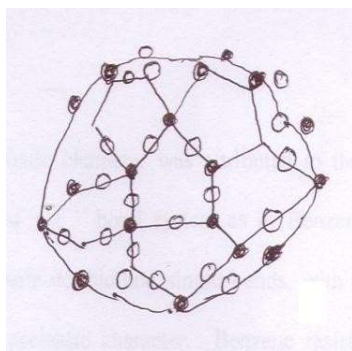
Buck Minster Fullerene

Fig 11

1.4   TAUTOMERISM

A single compound exists in two or more readily inter convertible structures, that markedly in relative positions of atleast one atomic nucleus, generally hydrogen. The two different structures are known as tautomers of each other.

This is a special type of functional isomerism where the isomers exist simultaneously in equilibrium with each other. The term tautomerism (Greek : tauto – Same; meros – parts) was used by Laar in 1885 to describe the phenomenon of a substance reacting chemically according to two possible structures.

The type of isomerism in which a substance behaves as it has two different structures is known as tautomerism and the different forms are called tautomers (or tautomerides). It is caused by the wandering of hydrogen atom between two polyvalent atoms. It is also known as Desmotropism (desmos = bond and tropos = turn). If the hydrogen atom oscillates between two polyvalent atoms linked together, the system is a dyad and if the hydrogen atom travels from first to third in a chain, the system is a triad.

1. Hydrocyanic acid is an example of dyad system in which hydrogen atom oscillates between carbon and nitrogen atoms.

$$H-C\equiv N \rightleftharpoons C\equiv N-H$$

2. **Triad System**

   (i)   Keto-enol system : Polyvalent atoms are oxygen and two
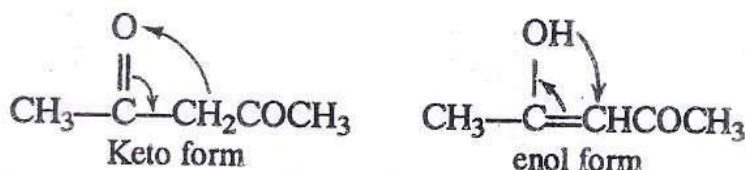   carbon atoms.

Examples :

(a) Acetoacetic ester :
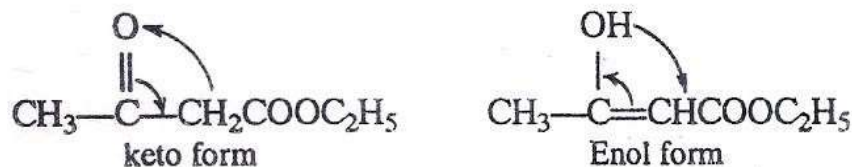
Acetoacetic ester gives certain reactions showing the presence of keto group (reactionswith HCN, H_2NOH, $H_2NNHC_6H_5$, etc.) and certain reactions showing the presence of enolic group (reactions with Na, CH_3COCl, NH_3, PCl_5, etc.)
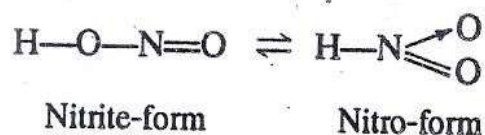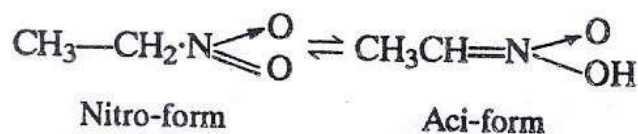
(b) Acetyl acetone :

(ii) Triad system containing nitrogen :

Examples :

(a) Nitrous acid :

(b) **Nitroethane :**

Characteristics of Tautomerism :

1.   Tautomerism (cationotropy) is caused by the oscillation of hydrogen atom between two polyvalent atoms present in the molecule. The change is accompanied by the necessary rearrangement of single and double bonds.

2.   It is a reversible intramolecular change.

3.   The tautomeric forms remain in dynamic equilibrium. Hence, their separation is a bit difficult. Although their separation can be done by special methods yet they form a separate series of stable derivatives.

4.   The two tautomeric forms differ in their stability. The less stable form is called the labile form. The relative proportion of two forms varies from compound to compound and also with temperature, solvent, etc. The change of one form into another is also catalysed by acids and bases.
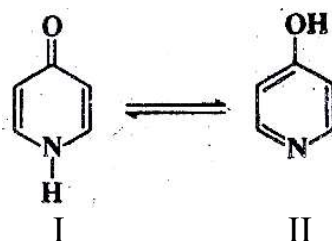
Other Proton-Shift Tautomerism

In all such cases, the anion resulting from removal of a proton from either tautomer is the same because of resonance. Some examples are :

1.   Phenol-keto tautomerism.

Phenol   Cyclohexadienone
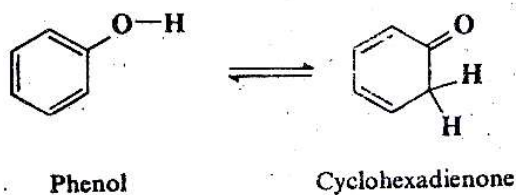
For most simple phenols this equilibrium lies well to the side of the phenol, since only on that side is there aromaticity. For phenol itself there is no evidence for the existence of the keto form. However, the keto form becomes important and may predominate : (1) where certain groups, such as a second OH group or an N = O group, are present; (2) in systems of fused aromatic rings; in heterocyclic systems. In many heterocyclic compounds in the liquid phase or in solution the keto form is more stable, although in the vapor phase the positions of many of these equilibraria are reversed. For example in the equilibrium between 4-pyridone (I) and 4-hydroxypyridine (II), I is the only form detectable in ethanolic solution, while II predominates in the vapor phase.
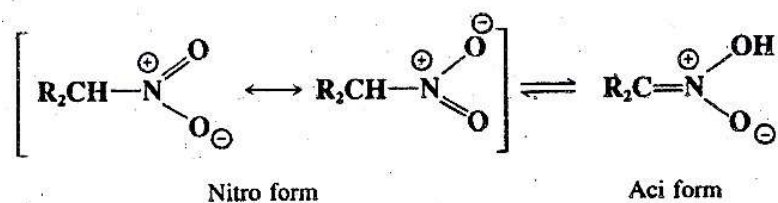
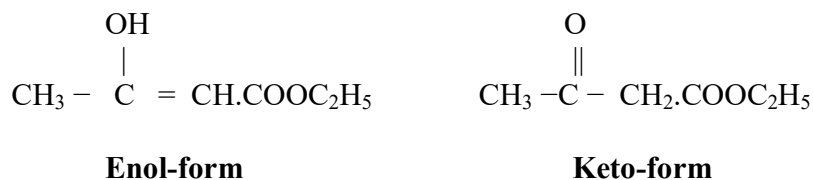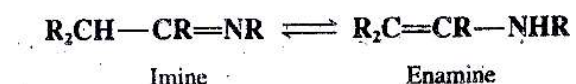

2.   Nitroso-oxime tautomerism :

$$R_2CH—N{=}O \rightleftharpoons R_2C{=}N—OH$$
$$\quad\text{Nitroso} \qquad\qquad \text{Oxime}$$
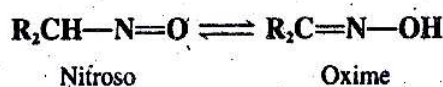
This equilibrium lies far to the right, and as a rule nitroso compounds are stable only when there is no α - hydrogen.

3.   Alphatic nitro compounds are in equilibrium with aci forms.

Nitro form   Aci form

The nitro form is much more stable than the aci form in sharp contrast to the parallel case of nitroso-oxime tautomerism, undoubtedly because the nitro form has resonance not found in the nitroso case.

4.   Imine-enamine tautomerism.

$$R_2CH-CR=NR \rightleftharpoons R_2C=CR-NHR$$

Imine   Enamine

$$CH_3 - \overset{\overset{\displaystyle OH}{|}}{C} = CH.COOC_2H_5 \qquad CH_3 - \overset{\overset{\displaystyle O}{||}}{C} - CH_2.COOC_2H_5$$

Enol-form   **Keto-form**

This is also known as dynamic isomerism. Tautomerism is a intermolecular change. It occurs due to the displacement of valence bond on reversible H-atom.

1.5   AROMATICITY

The aromatic character was attributed to the presence of a planner, cyclic conjugated π bond system as in benzene. Thus cycle polymer possessing alternate double and

single bonds, with a planner structure were shown to have aromatic character. Benzene resist addition and oxidation reactions besides highly unsaturated and has three π bonds. It is stable due to low-heat of hydrogenation, instauration and planarity of the molecule and hence chemically stable.

A most significant feature of benzene and other compounds containing this ring system is that they are more stable in comparison to the corresponding acyclic polyenes. Such compounds posses large resonance energies and are called aromatics. The extra stability of such compounds is ascribed to a special property referred to as aromatic character or aromaticity. Since benzene is a cyclic conjugated polyene, earlier chemists thought that the lower and higher vinylogues of benzene, for instance, cyclobutadiene and cyclooctatetraene could also be prepared and they should exhibit aromaticity. But the fact is that the former compound is highly unstable while the latter though prepared does not possess comparable stability and behaves like an ordinary polyene with isolated double bonds. Evidently aromaticity is related to some characteristic feature of benzene and related systems – generally having some 'magic' number of π electrons in a regular, planar, monocyclic polymethine.
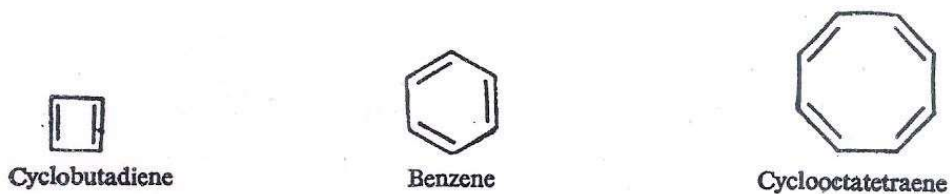

Cyclobutadiene   Benzene   Cyclooctatetraene

Fig 12.

Ring compounds, having an even number of CH units represented as neutral monocyclic polyenes, $(-CH = CH -)_n$ are also referred to as annulenes. It was Hückel who in 1931 formulated a simple rule for predicting whether or not a given annulene would be aromatic. This rule, commonly referred to as Hückle's rule, states that a conjugated polymethine will be aromatic, if and only if, it contains $(4q + 2)$ π electrons, where $q = 0, 1, 2, 3, ...$ etc. On the other hand, if such a system contains $4q\pi$ electrons it will not be aromatic, i.e., it will either be antiaromatic or non-aromatic.

In Benzoid compounds one or more fused Benzene rings as found, such compounds obey Huckel rule but acenaphthalene and diphenylene do not obey **Huckel rule**.
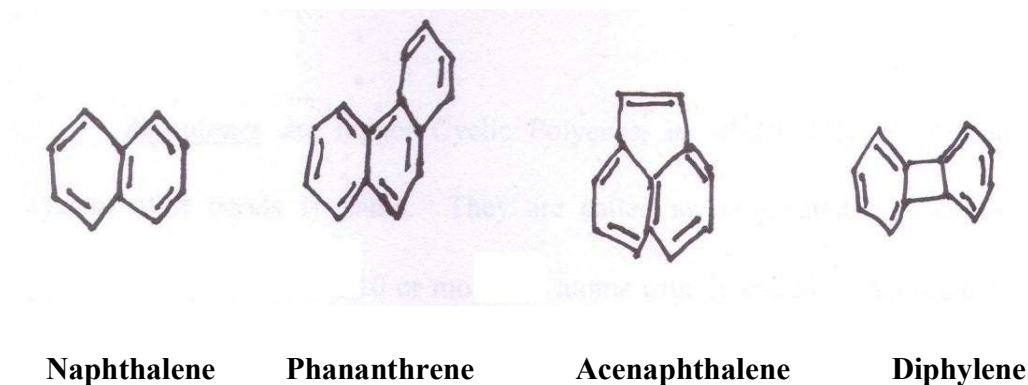

Naphthalene   Phananthrene   Acenaphthalene   Diphylene

Fig 13.

Benzonoid aromatic compounds atleast having one sexlets of π electrons benzonoid ring.

Non-benzonoid aromatic compounds have different planar cyclic _C' skelton, but they obey Hyckel rule, althought hetrocyclic compounds also obey **Huckel rule**.

1.5.1 Huckel rule

Non-bezonoid compounds, although does not contain a Benzene ring yet exhibit a degree of aromatic character typical of Benzene e.g.

   a)   Three measured Carbocyclic Compounds :

   i.   Cylopropene cation.

   ii.   Cyclopentadiene anion

   iii.   Acetylation

Thus Huckel has given molecular orbital theory in 1938, that such planer cyclic system having conjugated double bonds shows aromatic character. They have $(4\eta + 2)\pi$ electrons. η = integer it may be 0, 1, 2, 3, 4…… energy levels.

Annulenes are higher Cyclic Polyenes, in which fully conjugated system of π bonds is found. They are called as conjugated monocyclic polyenes $(C\eta H\eta)$. It has 10 or more _C' atoms usually called as **Annulenes**. It is also called as (η) Annulene, where η = no. of C atoms present in Benzene ring e.g. Benzene is (6), Annulene – 10.
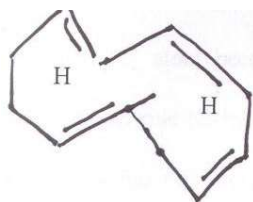
η = 12, 14, 16, 18, 20, 24, 30.

Bucket shaped

From quantum mechanical point of view, an aromatic system is the one that possesses a closed shell of π electron system of any regular, planar, cyclic, conjugated polymethine reveals that energies of the molecular orbitals in such systems have a very simple characteristic pattern. In these systems there is always one orbital of lowest energy which is followed by degenerate pairs of orbitals (i.e., orbitals in such systems have a very simple characteristic pattern. In these systems there is always one orbital of lowest energy which is followed by degenerate pairs of orbitals (i.e., orbitals having same energy) in the order of incrasing energy and finally there is one orbital of highest energy. Filling of electrons in these orbitals takes place in the following manner : first of all two electrons are filled in the lowest orbital and then the rest of the electrons go to the degenerate pairs of orbitals strictly according to Hund's rule. Thus, in an annulene (- CH = CH -)$_n$, if n is an even number, the lowest orbital will always be filled by two electrons and other orbitals being filled in the manner described above. But there will always be two singly occupied degenerate orbitals in such systems. Because of this arrangement of electrons, such systems are highly unstable and are termed as antiaromatic. For instance, cyclobutadiene (n = 2; 4q π electrons) would be antiaromatic because out of 4π electrons, two would fill the lowest orbital and the remaining two would go to the first pair of degenerate orbitals, each being singly occupied. As expected, cyclobutadiene would be an antiaromatic compound. On the other hand, when n is an odd number out of $4q+2\pi$ electrons two would fill the lowest orbital, then each of the q degenerate pairs of orbitals would be occupied by 4 electrons. Because of this closed shell filling of orbitals

with electrons, such compounds are aromatic. For instance, benzene (n=3) having 6 π electrons (4q+2) is aromatic. This set of 6 π electrons of benzene is also called an aromatic sextet. This explains the stability of (4q+2) vis-a-vis (4q) π electron systems which are antiaromatic as they possess higher energy than the hypothetical structures having independent double bonds without mutual overlap, that is without delocalization. The orbital energy diagrams of some of the important systems such as chclopropenyl cation (4q+2; q=0), cyclobutadiene (4q; q=1), benzene (4q + 2; q=1), cyclooctatetraene (4q; q=2) and cyclodecapentaene (4q+2; q=2) shown assuming that they are regular and planar (cyclooctatetraene is, however, a non-planar compound).

Benzene provides an illustrative example which shows a six proton singlet at δ 7.27. Thus nmr spectral study leads to an excellent spectroscopic test of aromaticity and this has been successfully applied to the other members of the annulene series. The annulenes having (4q+2) π electrons show similar behaviour in their low temperature nmr spectra which exhibit lowfield signals due to external protons and the internal protons show upfield signals as expected. On the other hand, annulenes with 4q π electrons show low field and upfield signals due to internal and external protons, respectively. Such annulenes are antiaromatic. Thus, for instance, [16] annulene shows in its nmr spectrum at room temperature all the protons located at δ 6.7 but at $- 110^{o}$ it shows a four proton signal at much lower field strength and a 12 proton multiple at higher field strength
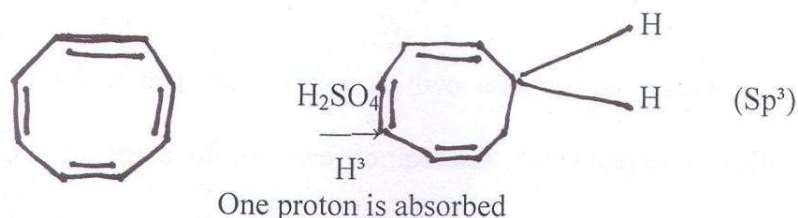
1.5.2 Anti-Aromaticity

For such short cyclic conjugated system having delocalized electrons are aromatic in nature. These systems are thermodynamically less stable than acyclic system and leads only 4η π electrons
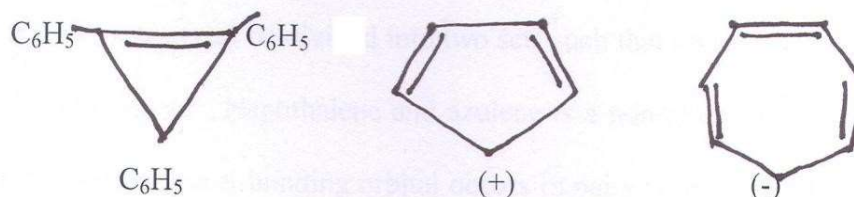
Terphenyl Cyclopropenyl   Cyclopentadienium   Cyclopheplatrienyl

anion   cation

1.5.3 Homo-Aromaticity

One _C' atom becomes saturated (Sp^3) aromatic compound which follows Huckel rule having 3 double bond i.e. 6 π electrons shows aromatic character. It has fully conjugated structure having 1 or 2 Sp3 Carbon, are known as Homo-aromatic compounds.

One proton is absorbed

Cyclo-octatetraene

1.6   ALTERNANT AND NON-ALTERNANT HYDROCARBONS

Aroamatic Hydrocargons are divided into two types. In alternant HC the conjugated

_C' atoms can be divided into two sets such that no two atoms of the same set are

directly linked. Naphthalene and azulene is a non-alternant HC. In alternant HC, the

bonding and anti-bonding orbital occurs in pairs is for every bonding orbital with an

Energy E. There is anti-bonding one with Energy + E (1) even alternant HC are those
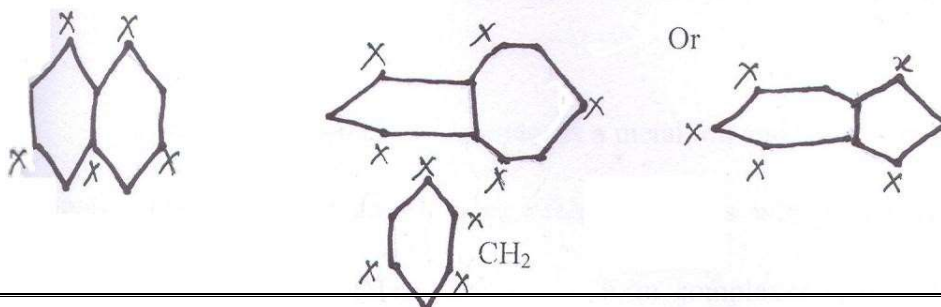
Odd alternant Hydrocarbon

with an even no. of conjugated atom is an equal no. of saturated and unsaturated atoms.

1.7 BONDS WEAKER THAN CO-VALENT BONDS

BONDING WEAKER THAN COVALENT

The structure of molecules each of which is an aggregate of atoms in a distinct three-dimensional arrangement held together by bonds with energies on the order of 50 to 100 kcal/mol,. There are also very weak attractive forces between molecules, on the order of a few tenths of a kilocalorie per mole. These forces, called van der waals forces, are caused by electrostatic attractions such as those between dipole and dipole, induced dipole and induced dipole, etc, and are responsible for liquefaction of gases at sufficiently low temperatures.

HYDROGEN BONDING :

A hydrogen bond is a bond between a functional group A – H and an atom or group of atoms B in the same or a different molecule. With exceptions to be noted later, hydrogen bonds are formed only when A is oxygen, nitrogen, or fluorine and when B is oxygen, nitrogen, or fluorine. The oxygen may be singly or doubly bonded and the nitrogen singly, doubly, or triply bonded. The bonds are usually represented by dotted lines, as shown in the following examples:

ADDITION COMPOUNDS :

When the reaction of two compounds results in a product that contains all the mass of the two compounds, the product is called an addition compound. There are several kinds of addition compounds. In these addition compounds, the molecules of the starting materials remain more or less intact and weak bonds hold two or more molecules together. We can divide these compounds into four broad classes : electron donor-acceptor complexes, complexes formed by crown ethers and similar compounds, inclusion compounds, and catenanes.

It is know that the reaction of two compounds results in a product that contains all the mass of the two compounds, the product is called an addition compound. There are number of kinds, in which of the starting materials remain more or less intact and weak bonds hold two or more molecules together. They are of four kinds:-

1.7.1   Electron donor-accepter complexes,

1.7.2   Complexes formed by crown ethers and similar compounds,

1.7.3   Inclusion compounds and

S1.7.4   Catenanes.

1.7.1 Electron Donor-Acceptor Complexes (EDA)

In EDA complexes, there is always a donor molecule and an acceptor. The donor may donate an unshared pair (an n donor) or a pair of electrons in a π orbital of a double bond or aromatic system (a π donor). One test for the presence of an EDA complex is the electronic

spectrum. These complexes generally exhibit a spectrum (called a charge-transfer spectrum) that is not the same as the sum of the spectra of the two individual molecules.

EDA complexes are often colored. Many EDA complexes are unstable and exist only in solutions in equilibrium with their components, but others are stable solids. In most EDA complexes the donor and acceptor molecules are present in an integral ratio,

There is always a donor molecule and an acceptor in EDA complexes. The donor may donate an unshared pair (an π donor) or a pair of electrons in a π orbital of a double bond or aromatic system (a π donor). These complexes are identified by Charge-Transfer Spectrum.

1.   Complex in which the acceptor is a metal ion and the donor an olefin or an aromatic ring (n donors do not give EDA complexes with metal ions but form covalent bonds instead). Many metal ions form complexes, which are often stable solids, with olefins, dienes (usually conjugated, but not always), and aromatic rings. The generally accepted picture of the bonding in these complexes, first proposed by Dewar, can be illustrated for the complex in which silver ion is bonded ton an olefin. There are two bonds between the metal ion and the olefin. One of these

$$\begin{array}{c} R_2C \\ \parallel \quad Ag^+ \\ R_2C \end{array}$$
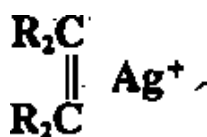
is a σ bond formed by overlap of the filled π orbital of the olefin with the empty 5s orbital of the silver ion, and the other is a π bond formed by overlap of a filled 4d orbital of the silver ion and an empty antibonding π* orbital of the olefin. The bond is not from the silver ion to one atom but to the whole π center. The net result is that some electron density is transferred from the olefin to the metal ion.

2.   Complexes in which the acceptor is an organic molecule. Picric acid, 1, 3, 5-trinitrobenzene, and similar polynitro compounds are the most important of these. Picric acid forms addition compounds with many


Picric acid
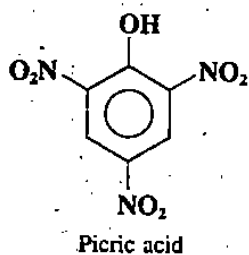
aromatic hydrocarbons, aromatic amines, aliphatic amines, olefins, and other compounds. These addition compounds are usually solids with definite melting points and are often used as derivatives of the compounds in question. They are called picrates, though they are not salts of picric acid but addition compounds. Unfortunately, salts of picric acid are also called picrates. Similar complexes are formed between phenols and quinones (quinhydrones). Olefins that contain electron-withdrawing substituents also act as acceptor molecules as do

certain anhydrides. A particularly strong olefin acceptor is tetracyanoethylene

Complexes in which the acceptor is a metal ion and the donor an olefin or a aromatic ring (π donors do not give EDA complexes with metal ions but form covalent bonds instead). Many metal ions form complexes stable solid (but not always). The result is that some electron density is transferred from olefin to metal ion.
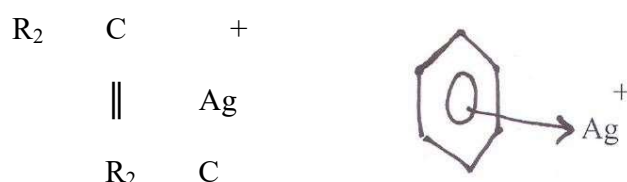

The donor (or legend) are Hepto and/or the descriptor η‖ (eta). The η‖ indicates no. of atoms ethane is a dihapto or η^2 legend and benzene hexa-hapto or η6 e.g. $C_6H_5 - Li$ (a mono-hapto or η' legend. In allyl Lithium, a Ơ bond connects the Carbon to the metal, the allyl group is referred to as mono-hapto or η'.
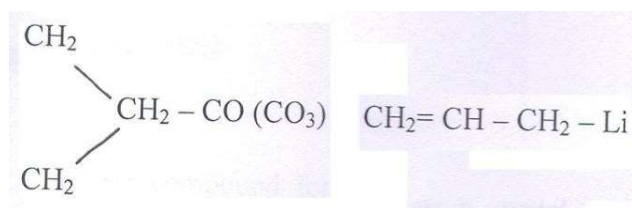
**Allyl Lithium**

1.7.2 Crown Ether Complexes and Cryptands

There are long-ring compounds containing several oxygen atoms, usually in a regular pattern e.g. 12-crown-4(A) dicyclohexano-18-crown-6(B) and 15-crown5 (c). They form complexes with positive ions, generally metal Ammonium etc. (not transitional atoms). Crown ether binds different ions depending on the size of cavity. They are useful in organic synthesis, have low M.P. Bi-clyclics and cycles of higher order are called cryptands and the compleyes formed are called cryptates (Mono-cyclics are also called cryptands). Crown ethers are large-ring compounds containing several oxygen atoms, usually in a regular pattern. Examples are 12-crown-4(4), dicyclohexano-18-crown-695), and 15-crown-5 (6). These compounds

I   II   III
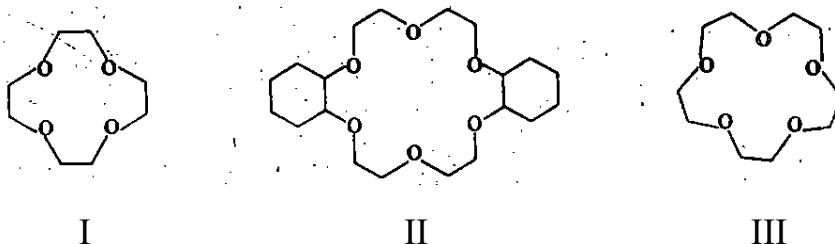
have the property of forming complexes with positive ions, generally metallic ions (though not usually ions of transition metals) or ammonium and substituted ammonium ions. In most cases the ions are held tightly in the center of the cavity. Each crown ether binds different ions, depending on the size of the cavity. For example, I binds Li^+ but not K^+, while 5 binds K^+ but not Li^+. Similarly, II binds Hg^{2+} but not Cd^{2+} or Zn^{2+}, and Sr^{2+} but not Ca^{2+}. The complexes can frequently be prepared as well-defined sharp-melting solids.

Macrocycles containing nitrogen or sulfur atoms, e.g., IV and V, have similar properties, as do those containing more than one kind of hetero atom, e.g., VI, VII, or VIII. Bicyclic molecules like 10 can surround the enclosed ion in three dimensions, binding it even more

tightly than the monocyclic crown ethers. Bicyclics and cycles of higher
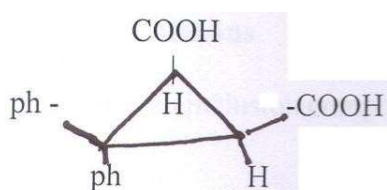order are called cryptands and the complexes formed are called cryptates

<table>
<tr><td>IV</td><td>V</td><td>VI</td><td>VII</td></tr>
</table>
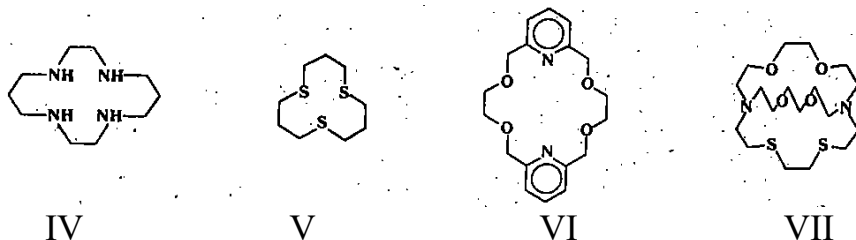
(monocylies are also sometimes called cryptands). The tricyclic cryptand
VIII has ten binding sites and a spherical cavity. Another molecule with a
spherical cavity (though not a cryptand) is IX, which complexes Li^+ and
Na^+ (preferentially Na^+), but not K^+, Mg^{2+}, or Ca^{2+}. Molecules such as
these, whose cavities can be occupied only by spherical entities, have
been called spherands.

The bonding in these complexes is the result of ion-dipole
attractions between the hetero atoms and the positive ions.

VIII   **IX**
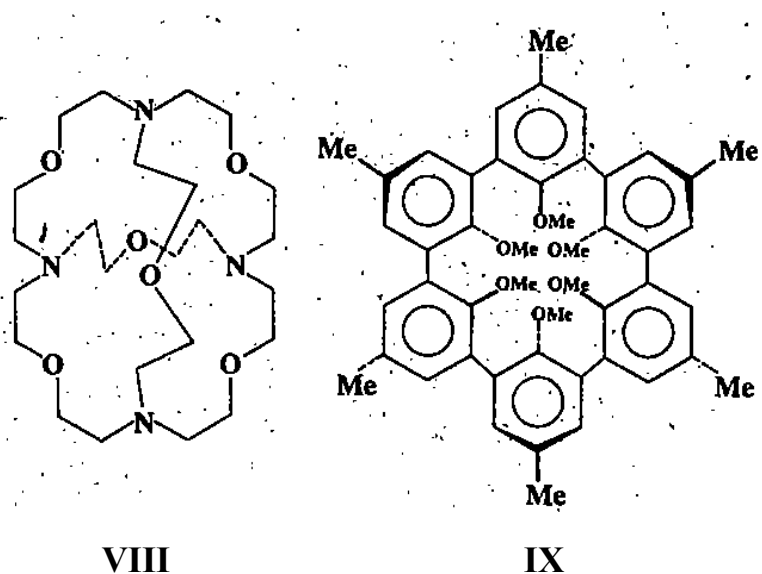
1.7.3 Inclusion Compounds

The host compound forms a crystal lattice, which has spaces large enough for the guest to fit into. There is no bonding between the host and the guest except vander-woals forces. There are two main types; depending on the shape of the space. The spaces _in inclusion compounds am in the shape of long tunnels Or-channels, while the other type, often called clathrate, or cage compounds have spaces that are completely enclosed. In both types the guest molecule must fit into the space and potential guests that are too large or too small will not go into the lattice, so that the addition compound will not form.

- The most important host molecule among the-inclusion compounds is urea. Ordinary crystalline urea is tetragonal but when a guest is present urea crystallizes in a hexagonal lattice containing the guest in long channels. The hexagonal type of lattice can form only when a guest molecule is present, showing that van der Waals forces between the host and the guest, while small, are essential to the stability of the structure. The diameter of the channel is about 5Å, and which molecules can be guests is dependent

only on their shapes and sizes and not on any electronic or chemical effects. For example, octane and l-bromooctane are suitable guests for urea, but 2-bromooctane, 2-methylheptane, and 2-methyloctane are not. Also both dibutyl maleate and dibutyl fumarate are guests; neither diethyl maleate or diethyl fumarate is a guest, but dipropyl fumarate is a guest and dipropyl maleate is not. In these complexes, there is usually no integral molar ratio (though by chance there may be). For example, the octane-urea ratio is 1:6.73.

- **Cyclodextrins**

There is a compound or one type of host that can form both channel and cage complexes, called cyclodextrins and cycloamyloses. The host molecules are made up of 6, 7 or 8 glucose units connected in large ring called respectively α, β or γ cyclodextrin. These are channel type complexes. The host stacked on top of each other.

1.7.4 Catanans and Rotaxanes

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Catenanes and Rotaxanes

These compounds contain two or more independent portions that are not bonded to each other by any valence forces but nevertheless must remain linked. Catenanes are made up of two or more rings held together

A [2]catenane   A [3]catenane   A rotaxane
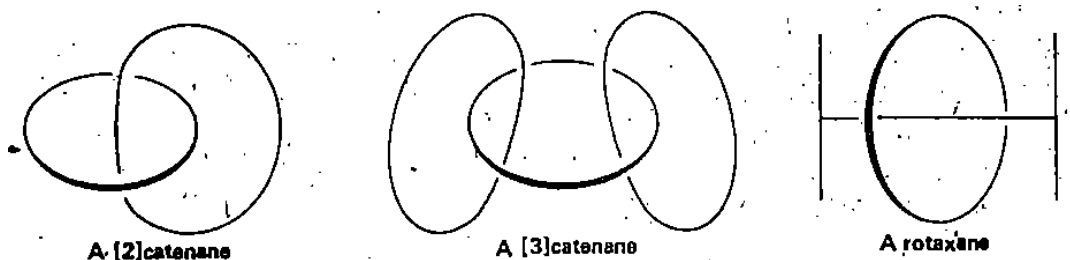
as links in a chain, while in rotaxanes a linear portion is threaded through a ring and cannot get away because of bulky end groups. Catenanes and rotaxanes can be prepared by statistical methods or directed syntheses. An example of a statistical synthesis of a rotaxane is a reaction where a compound A is bonded at two positions to another compound B in the
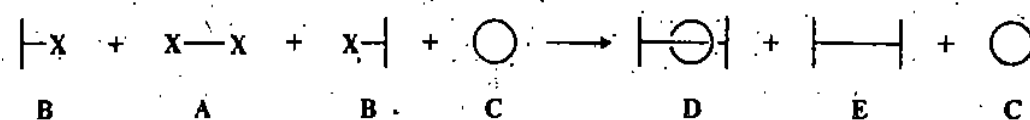
presence of a large ring C. It is hoped that some A molecules would by chance be threaded through C before combining with the two B molecules, so that some rotaxane (D) would be formed along with the normal product E.

1.8   STEREO-CHEMISTRY

Introduction

In Organic Chemistry, two or more compounds have same number of _C' atoms and possess same molecular formula but differ in their chemical and physical properties, are called Isomers and the phenomena is called Isomerism. They are of two types:

1)   Structural Isomerism

2)   Stereo Isomerism

1)   **Structural Isomerism** – Due to difference in the arrangement of atoms within the molecule, without any reference to space, may be chain, positional, functional and metamerism.

2)   **Stereo Isomerism –** The different arrangement of atoms or group in space. The compound had same structural formula but differ in special arrangement of atoms or groups in the molecule e.g. Geometrial (cis-Trans), Optical Isomerism.

Confirmational Analysis of Cycloalkanes

As a regular planar cycloalkane structure with _C' atom at the corners would make the C – C – C bond angle 120° i.e. deviation of nearly 10° from normal tetrabedral angle of 109° 28‖, Baeyer's Strain Theory cyclo-hexane and higher cycloalkanes are found to be quite stable due to puckering of the ring. The normal valency angle is retained and a strain less ring is produced e.g. chair and boat conformations. In chair, the _H' atoms are staggered the torsional strain is minimum and hence stable.
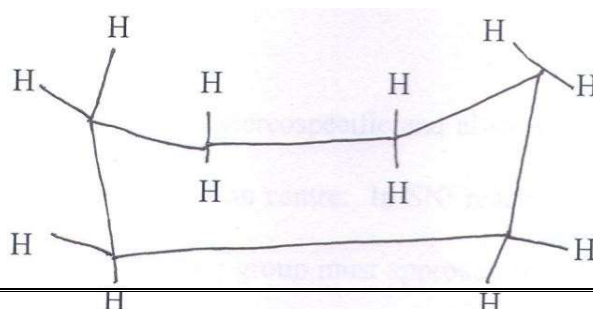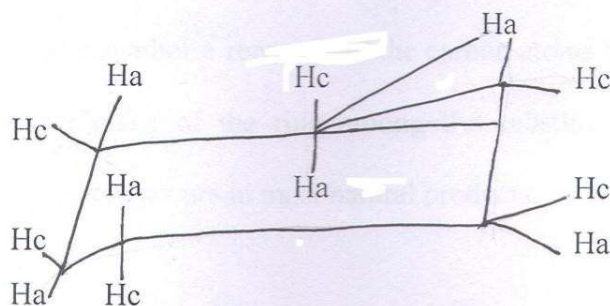
Although boat form is strain free but factors which make the boat from unfavourable. Hence boat form is less stable than chair form.

In Bicyclic system, fused ring system, in the study of conformation of this group is ‒decalin‖. They may fuse in Cis and Trans manner.

| CIS | TRANS |
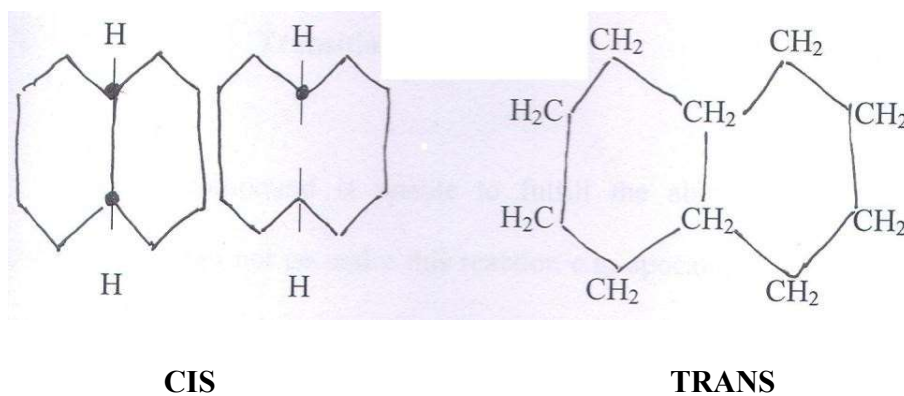
The symbol ● represented the carbon atoms having the hydrogen atoms above the plane of the ring among the substituted decations, the methyl declain system occurs in most natural products.

| **Check your progress – 2** |
| Notes :-   1.   Write your answers in the space given below.
          3.   Compare your answers with those given at the end. |
| a)   Streo-Chemistry
     b)   Tautomerism
     c)   Methods of Resolution
 ……………………………………………………………………………………
 ……………………………………………………………………………………
 ……………………………………………………………………………………
 …………………………………………………………………………………… |

1.9   EFFECT OF CONFIRMATION ON REACTIVITY

SN^2 reactions are stereospecific and always proceed with inversion of configuration at the reaction centre. In SN^2 reactions stereo-electronic factor requires that the incoming group must approach from the opposite side of the leaving group.
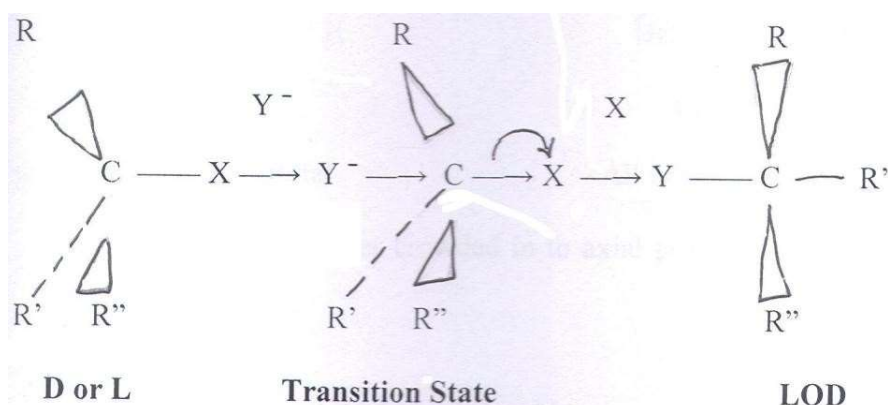

If the compound is unable to fulfill the above stereo-electronic requirement, it can not go under this reaction e.g. apocamphyl chloride. The steoric hindrance and strain due to over crowding are also in some way responsible for such reactions.

Confirmation of Sugars

D (+) glucose contains six membered, pyranose rings nearly equal to similar cyclo-hexane ring. It should be puckered and to minimize torsional and vander-woals strain should exist in two chain forms in preference to twist-boat confirmation.
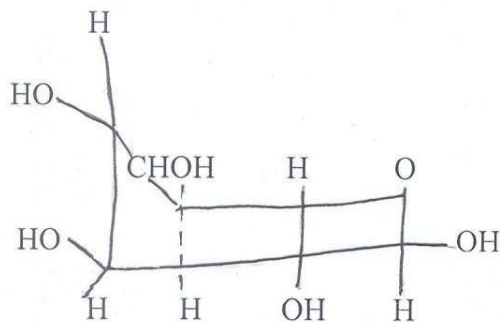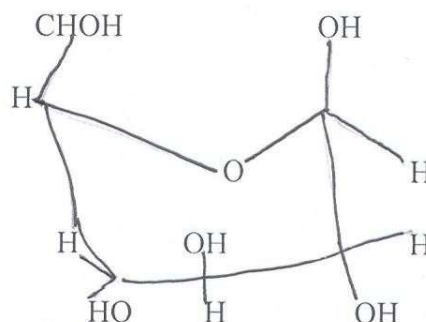
More stable   Less stable

All bulky group equatorial   All bulky group axial.

The bulky groups are over crowded in to axial position and not equatorial hence unstable.

Steric strain due to unavoidable crowding

Steric strain exists in a molecule when bonds are forced to make abnormal angles which results in a higher energy. Even smaller groups can sterically interfere in ortho positions. In hexaisopropyl benzene, the six isopropyl groups are so crowded that they can not rotate but are linked up around the benzene ring all pointed in the same director, as interlocked gears.

There are many other cases of Intra-molecular crowding that results in the distortion of bond angles e.g. hexahelicene and bent benzene rings. Although the steric effects are non-additive in crowded molecules.
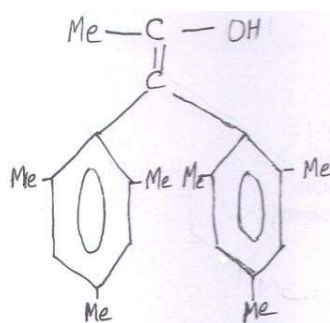

1.10   ELEMENT OF SYMMETRY

The super impossibility of mirror image of a molecule is the basic concept of Symmetry, if not then asymmetrical.   The asymmetrical molecule is optically active. If a molecule contains anyone after following symmetry then it is optically active.

1.   **Plane of Symmetry:** When similar types of groups or atoms are on the same side and the molecule can be divided into two equal parts, there is plane of symmetry.
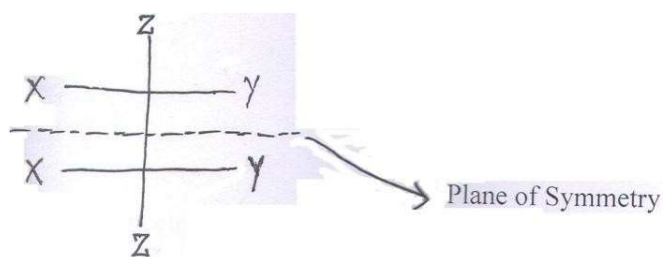
2.   **Centre of Symmetry:** The point within the molecule such that straight lines drawn through the centre point meet identical atoms or groups in both directions from that point. Even numbered rings have a centre of symmetry.
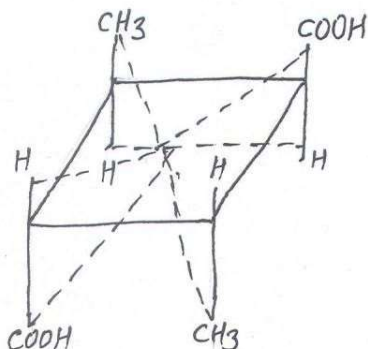
2, 4, dimethyl cyclo-butane
1, 3 dicarboxylic acids have Centre of Symmetry

3.   **Axis of Symmetry:** A line which posses through the molecule, so that a rotation of $\frac{360}{}$ about this axis gives a three-dimensional structure, which is same as the original. All molecules possess a one fold symmetry ($\eta = 1$) since rotation of 360˚ about any Axis leads to identical structures e.g. Methane has a three fold axis of symmetry along each C – H bond.
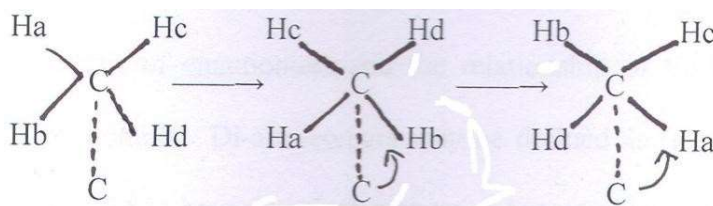

1.11 CHIRALITY

The molecule exhibit optical Isomerism when their Geometric Structure of it is non-superimpossible on its mirror image. Enantiomorphs (mirror image) are related to each other as right hand to left hand such molecule are said to posses Chirality e.g.

carbon atom of 2 Butanol carrying four compounds different groups – H, -OH, -CH_3, -C_2H_5 in the Chiral Atom or the ‖Chiral centre‖ in the molecule. The molecule is asymmetric. In organic chemistry asymmetric ‗C' atoms are the Chiral Centres, which causes optical activity.

$$\overset{*}{CH_3CH_2CHOH}\ CH_3$$

   * Chiral Carbon
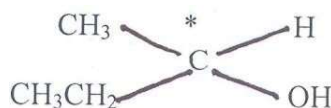
1.11.1 Molecules with more that one Chiral Centres

When a molecule has two Chiral Centres, each has its own configuration and can be classified R or S by the Cahn-In gold-prelog Method. There is total no. of four isomers, since the first cenrtre may be R or S and so may be second. Since a molecule can have only one mirror image, only one of the other three can be enantiomers of A. This is B (the mirror image of an R Centre is always an S centre). C&D are a second pair of enautiomers and the relationship of C&D to A&B is designated as di-astereomers. Di-astereomers may be defined as stereoisomers that are not enantiomers. C&D have identical properties but not identical with A &B. The properties are usually similar but not identical. In particular, di-astereomers have different specific rotations, indeed diastereomer may be Chiral and rorate the plane polarized light, while another may be achiral and not rotate of all.

Although four is the maximum possible number of isomers when the compound has two chiral centres. Chiral compounds without a chiral ‗C' or with one chiral ‗C' and

51

another type of chiral centre. When three groups in one chiral atom, are the same as those on the other, one of the isomers (called meso) has plane of symmetry and hence optically inactive, even though it has two chiral _C' e.g. Tartaric Acid.


| A | B | C | D | Meso |
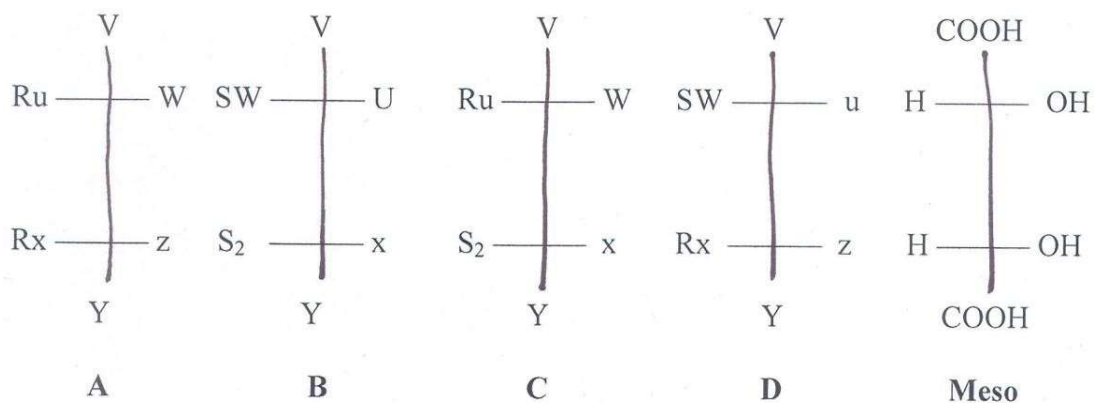
1.11.2 Methods of Resolution

The process of separation of a racemic modification into two pure eantioisomers is called Resolution. The separation can be effective only as fractional X'tallization or distillation. Only resolution is via diastereomers and resolution by bio-chemical methods are of practical importance.

1.   Convesion of Diastereomers.

2.   Differential absorption

3.   Chiral recognition

4.   Bio-chemical processes

5.   Mechanical separation

6.   Kinetic resolution is the main process of Resolution.

1. *Conversion to diastereomers.* If the racemic mixture to be resolved contains a carboxyl group (and no strongly basic group), it is possible to form a salt with an optically active base. Since the base used is, say, the S form, there will be a mixture of two salts produced having the configurations SS and RS. Although the acids are enantiomers, the salts are diastereomers and have different properties. The property most
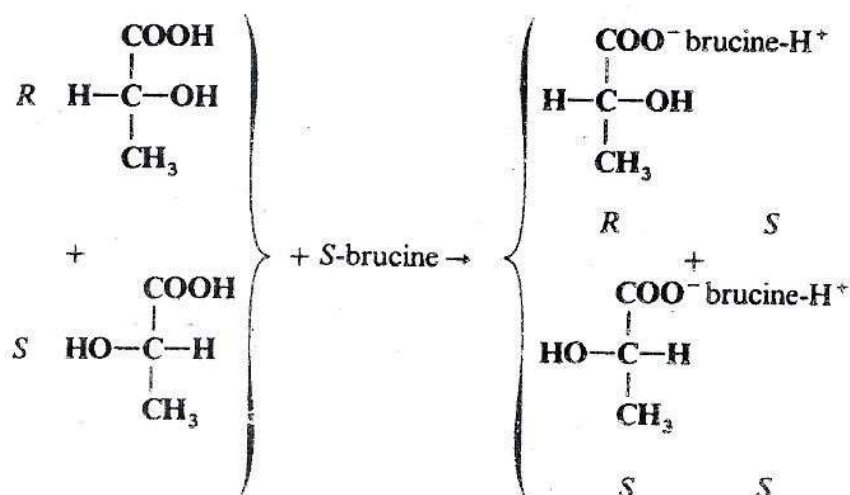
often used for separation is differential solubility. The mixture of diastereomeric salts is allowed to crystallize from a suitable solvent Since the solubilities are different, the initial crystals formed will be richer in one diastereomer. Filtration at this point will already have achieved a partial resolution. Unfortunately, the difference in solubilities is rarely if ever great enough to effect total separation with one crystallization. Usually fractional crystalizations must be used and the process is long and tedious. Fortunately, naturally occurring optically active bases (mostly alkaloids) are readily available. Among the most commonly used are brucine, ephedrine, strychnine, and morphine. Once the two

diastereomers have been separated, it is easy to convert the salts back to the free acids and the recovered base can be used again.

Although fractional crystallization has always been the most common method for the separation of diastereomers, its tediousness and the fact that it is limited to solids prompted a search for other methods. Fractional distillation has given only limited separation, but gas chromatography and preparative liquid chromatography have proved more useful and, in many cases, have supplanted fractional crystallization, especially where the quantities to be resolved are small.

2. *Differential absorption.* When a racemic mixture is placed on a chromatographic column, if the column consists of chiral substances, then in principle the enantiomers should move along the column at different rates and should be separable without having to be converted into diastereomers. This has been successfully accomplished with paper, column, thin-layer, and gas and liquid chromatography. For example, recemic mandelie acid has been almost completely resolved by column chromatography on starch. Gil-Av and others have achieved separations with gas and liquid chromatography by the use of columns packed with chiral absorbents. Columns packed with chiral materials are now commercially available and are capable of separating the enantiomers of certain types of compounds.

3. *Biochemical processes.* The chiral compound that reacts at different rates with the two enantiomers may be present in living organism. For instance, a certain bacterium may digest one enantiomer but not the other. This method is limited, since it is necessary to find the

proper organism and since one of the enantiomers is destroyed in the process. However, when the proper organism is found, the method leads to a high extent of resolution since biological process are usually very stereoselective.

4. *Mechanical separation.* This is the method by which Pasteur proved that recemic acid was actually a mixture of (+) – and (-) –tartaric acids. In the case of racemic sodium ammonium tartrate the enantiomers crystallize separately – all the (+) molecules going into one crystal and all the (-) into another. Since the crystals too are non-superimposable, their appearance is not identical and a trained crystallographer can separate them with tweezers. However, this is seldom a practical method, since few compounds crystallize in this manner. Even sodium ammonium tartrate does so only when it is crystallized below $27^{o}C$. A more useful variation of the method, though still not very common, is the seeding of a racemic solution with something that will cause only one enantiomer to crystallize. An interesting example of the mechanical separation technique was reported in the isolation of heptahelicene.

5. *Differential reactivity.* Since enantiomers react with chiral compounds at different rates, it is sometimes possible to effect a partial separation by stopping the reaction before completin. This method is very similar to the asymmetric syntheses. The most important application of this method is the resolution of racemic alkenes by treatment with optically active diisopinocampheylborane, since alkenes do not easily lend themselves to conversion to diastereomers if no other functional groups are present.

The process of separation of racemic modification into its two enantiomers is known as resolution. It becomes necessary to separate the racemic modification into its two pure enantiomers, called resolution is important for synthetic chemistry e.g. natural products. When isolation is not pure, then it is partical resolution. When two enantiomers are having similar physical properties can not be separated by physical methods e.g. tractional X'tallization or distillation, only resolution via diastereomers and biochemical methods are of practical importance.

1. **Conversion to Diastereomers** - The Chiral hast may also be used for separation. It gives only limited separation of solid of a racemic mixture e.g. racemic bases can be converted to diastereomeric salts with active acids. Alcohols can be separated diastereomeric esters, aldehydes to diastereomeric hydrozones etc. but Gas Chromatography and liquid chromatography supplement to this process.

2. **Differential absorption** - When racemic mixture is placed on a Chromatographic column and if consists of Chiral substance then enantiomers should move along the column at different rates and can be separated shold move along the column at different rates and can be separated without having to be converted into diastereomers, e.g. paper column, TLC and gas & liquid Chromatography.

3. **Bio-Chemical Processes** - The Chiral compounds that react at different rates with two enantiomers may be present in living organism e.g. certain bacteria may diagest one enentiomer but not other, but this method is limited, as suitable organism is a question.

4. **Mechanical Separation -** Pasteur used racemic acid was actually a mixture of (+) & (-) components e.g. sodium ammonium tartarate crystalise separately (+) goes one X'tal and X'tallizatin in Chiral additive. Subtimation is an other quick method.

5. **Kinetic Resolution -** The enantiomers react with Chiral compounds at different rates and effect partial separation by stopping the reaction before completion. It is just like asymmetric synthesis.

6. **Deracemization -** One enantiomer is converted to the other, so that a recemic mixture converted to pure enantiomer or mixture enriched in one enantiomer but the process is TDS.

1.12 OPTICAL PURITY

If a racemic mixture is resolved by the above methods (anyone), how we know that the enantiomers are pure. For example, how do we know that the (+) isomer is not contaminated by, say, 20% of the (-) isomer and vice versa? If we knew the value of $[\alpha]$ for the pure material ($[\alpha]_{max}$), we could easily

determine the purity of our sample by measuring its rotation. For example, if $[\alpha]$ max is $+80^{\circ}$ and our (+) enantiomer contains 20% of the (-) isomer, $[\alpha]$ for the sample will be $+48^{\circ}$. We define optical purity as

$$\text{Percent optical purity} = \frac{[\alpha]_{obs}}{[\alpha]_{max}} \times 100$$

Assuming that there is a linear relationship between $[\alpha]$ and concentration, which is true for most cases, the optical purity is equal to the percent excess of one enantiomer over the other :

$$\text{Optical purity} = \text{percent excess} = \frac{[R]-[S]}{[R]+[S]} \times 100 = \%R - RS$$

But how do we determine the value of $[\alpha]_{max}$? It is plain that we have two related problems here; namely, what are the optical purities of our two samples and what is the value of $[\alpha]_{max}$. If we solve one, the other is also solved. Several methods for solving these problems are known.

1.13 ENANTIOTOPIC AND DIASTEREOTOPIC, ATOMS GROUPS AND FACES

The two atoms or groups that upon replacement with a third group give enantiomers, are knows as eanantiotopic. Many molecule contain atom or groups, which appear to be equivalent but which in a close inspection will show to be actually different,

In the case of ethanol CH₂MeOH, if we replace one of the CH_2 hydrogens by a group Z, we get one enantiomer of the compound ZCHMeOH (X), while replacement of the other hydrogen gives the
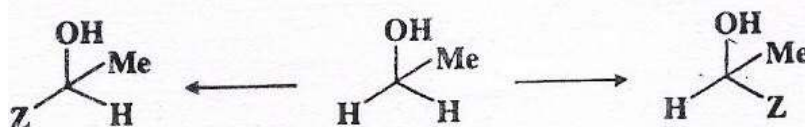

other enantiomer (XI). Since the two compounds which result upon replacement of H by Z (X and XI) are not identical but enantiomeric, the hydrogens are not equivalent. We define as enantiotopic two atoms or groups that upon replacement with a third group give enantiomers. In any symmetric environment the two hydrogens behave as equivalent, but in a dissymmetric environment they may behave differently. For example, in a reaction with a chiral reagent they may be attacked at different rates. This has its most important consequences in enzymatic reactions, since enzymes are capable of much greater discrimination than ordinary chiral reagents. An example is found in the Krebs cycle, in biological organisms, where oxaloacetic acid (XII) is converted to α-oxogulatric acid (XIV) by a sequence that includes citric acid (XIII) as an intermediate. When XII is


XII   XIII   XIV
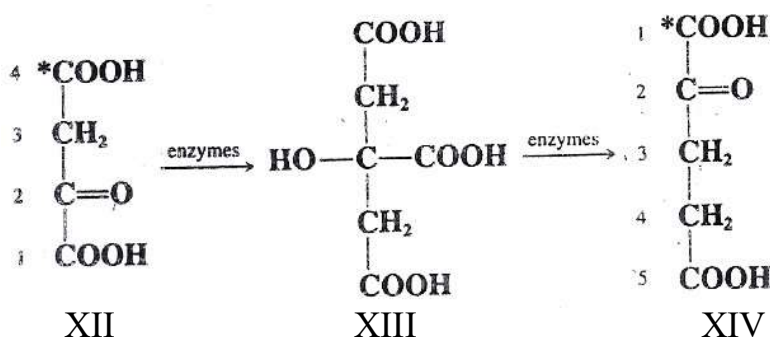
labeled with ^{14}C at the 4 position, the lebel is found only at C-1 of XIV, despite the fact that xIII is not chiral. The two CH_2 COOH groups of XIII are enantiotopic and the enzyme easily discriminates between them. Note that the X atoms or groups of any molecule of the form CX_2 WY are always enantiotopic if neither W nor Y is chiral.

The term *prochiral* is used for a compound or group that has two enantiotopic atoms or groups, e.g., CX_2WY. That atom or group X that would lead to an R compound if preferred to the other is called pro-R. The other is pro-S; e.g.,

$H^2 = pro\text{-}S$
$H^1 = pro\text{-}R$
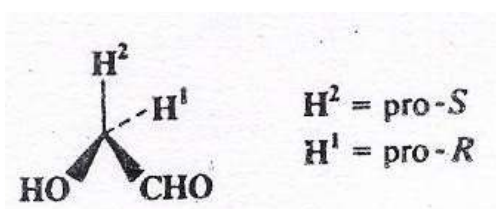
Where two atoms or groups in a molecule are in such positions that replacing each of them in turn by a group Z gives rise to diastereomers, the atoms or groups are called diastereotopic. Some examples are the CH_2 group of 2-chlorobutane (XV) and chlorocyclopropane (XVI) and the two olefinic hdyrogens of XVII. Note that in XVI one hydrogen from the CH_2 group is cis to the C1 while the other is trans, so that they are obviously
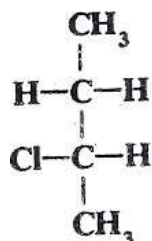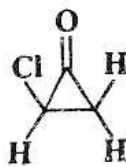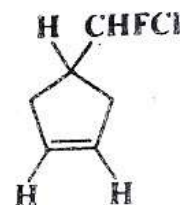
|		
XV	XVI	XVII

different. Diastereotopic atoms and groups are different in any environment, chiral or achiral. These hydrogens react at different rates with achieral reagents, but an even more important consequence is that in nmr spectra, diastereotopic hydrogens theoretically give different peaks and split each other. This is in sharp contrast to equivalent or enantiotopic hydrogens, which are indistinguishable in the nmr, except when chiral solvents are used, in which case enantiotopic (but no equivalent) protons give different peaks. The term isochronous is used for hydrogens that are indistinguishable in the nmr. In practice, the nmr signals from diastereotopic protons are often found to be indistinguishable.

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## 1.14 STEREOSPECIFIC AND STEREOSELECTIVE SYNTHESIS

In any reaction, in which only one of a set of stereo isomers is formed exclusively or predominantly is called Stereoselective Systhesis. The same term is used when a mixture of two or more stereoisomers is exclusively or predominantly formed at the expense of other stereo isomers.

In a stereospecific reaction, a given isomer leads to one product while another stereoisomer leads to the opposite product. All stereospecific reactions are necessarily stereoselective, but the converse is not true. These terms are best illustrated by examples. Thus, if maleic acid treated with bromine gives the *dl* pair of 2, 3-dibromosuccinc acid while fumaric acid gives the meso isomer (this is the case), the reaction is stereospecific as well as stereoselective because two opposite isomers give two opposite isomers :
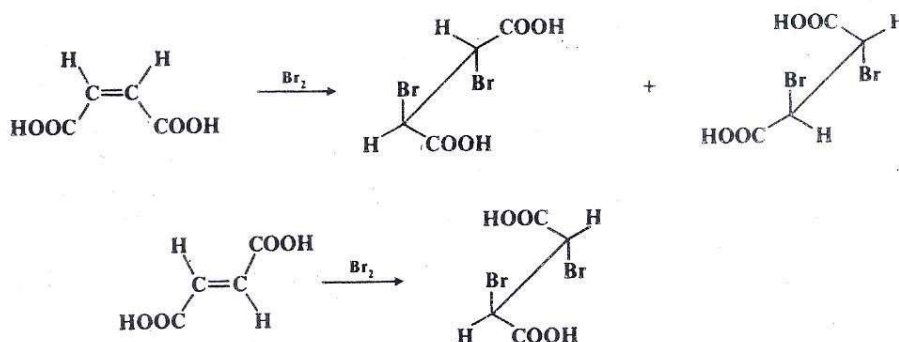

However, if both maleic and fumaric acid gave the *dl* pair or a mixture in which the dl pair predominated, the reaction would be stereoselective but not stereospecific. If more or less equal amounts of *dl* and meso forms were produced in each case, the reaction would be nonstereoselective. A consequence of these definitinos is that if a reaction is carried out on a compound that has no stereoisomers, if cannot be stereospecific, but at most stereoselective.

In allenes the central carbon is *sp*-bonded. The remaining two *p* orbitals are perpendicular to each other and each overlaps with the *p* orbital of one adjacent carbon atom, forcing the two remaining bonds of
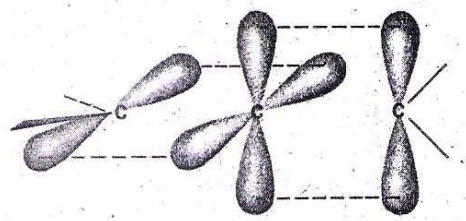
each carbon into perpendicular planes. Thus allenes fall into the category represented by Figure :

Mirror
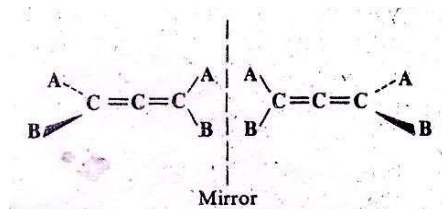
Like biphenyls, allenes are chiral only if both sides are dissymmetric.For example.

Inactive   Inactive   Active
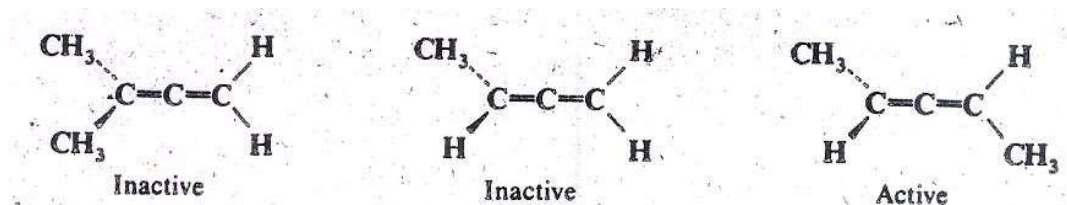
These cases are completely different from the cis-trans isomersim of compounds with one double bond. In the latter cases the four groups are all in one plane, the isomers are not enantiomers and neither is chiral, while in allenes the groups are in two perpendicular planes and the isomers are a pair of optically active enantiomers.

Amont other type of compounds that contain the system illustrated in Figure and that are similarly chiral if both sides are dissymmetric are spiranes, e.g. A and compounds with exocyclic double bonds, e.g. B


A   B
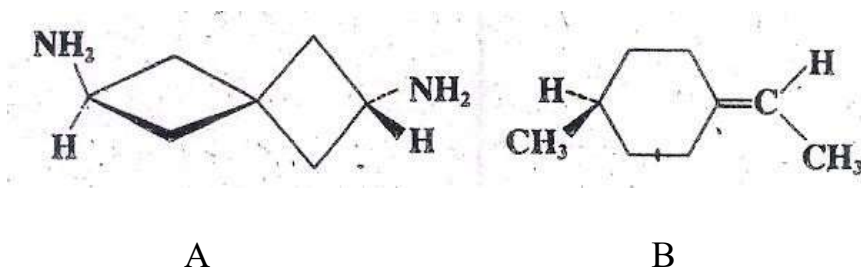
Compounds with other quadrivalent chiral atoms Any molecule containing an atom that has four bonds pointing to the corners of a tetrahedron will be optically active if the four groups are different. Among atoms in this category are Si,[1] Ge, sn, and N (in quaternary salts or N-oxides). In sulfones the sulfur bonds tetrahedrally, but since two of the groups are always oxygen, no chirality normally results. However, the preparation[19] of an optically active sulfone in which one oxygen is ^{16}O and the other ^{18}O illustrates the point that slight differences in groups are all that is necessary.
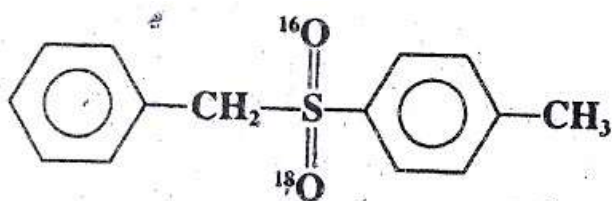
Compounds with tervalent chiral atoms. Atoms with pyramidal bonding might be expected to give rise to optical activity if the atom is connected to three different groups, since the unshared pair of electrons is

analogous to a fourth group, necessarily different from the others. For example, a secondary or tertiary amine where X, Y and Z are different
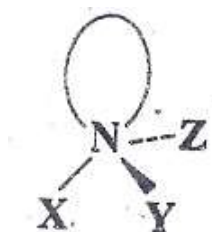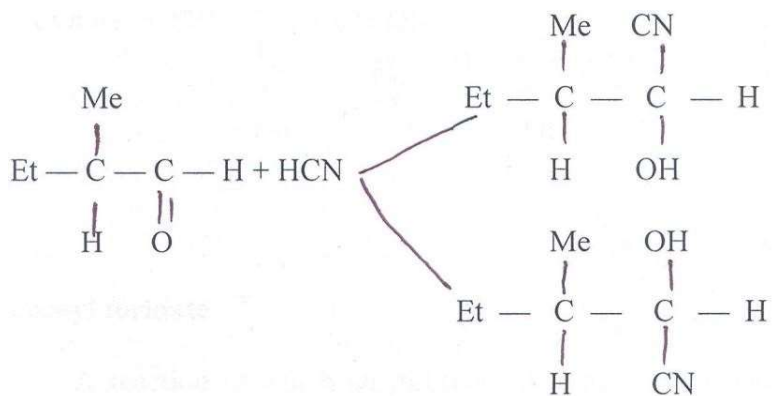

would be expected to be chiral and thus resolvable. Many attempts have been made to resolve such compounds, but until recently all of them failed because of the umbrella effect (also called pyramidal inversion).[21] The umbrella effect is a rapid oscillation of the unshared pair from one side of the XYZ plane to the other, thus converting the molecule into its enantiomer.

Asymmetric Synthesis

The optically active starting compound can be obtained by resolution of racemic mixture it is more often obtained in nature e.g. acid, sugars and steroids are regarded as chiral pool as starting material. The other method is Asymmetric Synthesis or Stereo-selective Synthesis as discussed in four heading.

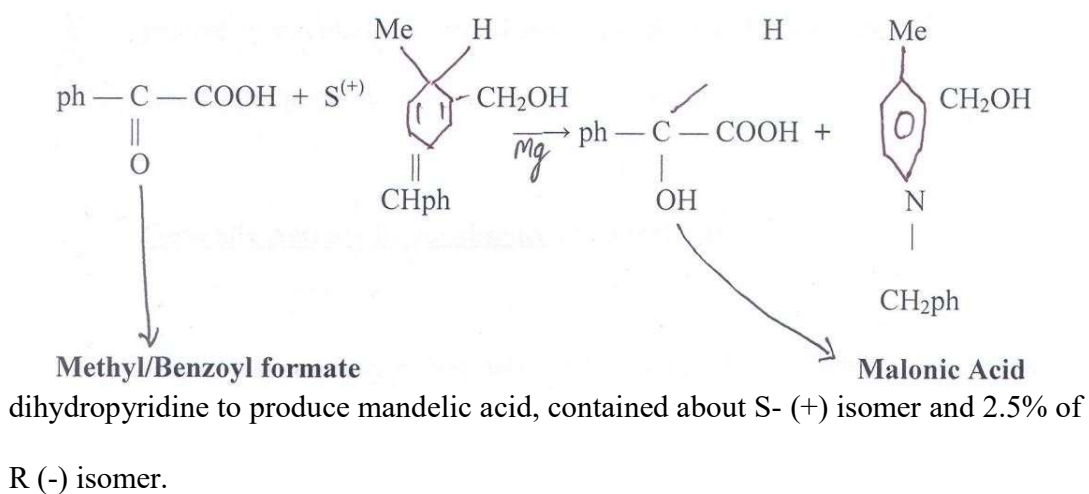**1.   Active Substrate** - In a new chiral centre is created in a molecule that is already optically active the two diastereomers are found in equal amounts. Reason is that the direction of attack, by the reagent, determined by the groups, is already there.

In certain additions to the Carbon-Oxygen, double bond of Ketones containing an asymmetric α-carbon atom.

Cram's rule predicts which diastereomer will predominate.

2. **Active Reagent** - A pair of enantiomers can be separated by an active reagent that reacts faster with one of them than it does with the other. (This is also a method of Resolution). Creation of a new Chiral Centre in an inactive molecule can be accomplished with an active reagent, though it is rare e.g. reduction of methyl benzoyl format with optically active N-benzyl- 3-hydroxymethyl - 4-methyl-1, 4-

Methyl/Benzoyl formate

Malonic Acid

dihydropyridine to produce mandelic acid, contained about S- (+) isomer and 2.5% of R (-) isomer.

A reaction in which an inactive substrate is converted selectively to one of two enantiomers is called enantio selective and process is asymmetric induction.

3. **Active Catalyst or Solvent** - The reduction of Ketones and substituted alkenes to optically active, secondary alcohols and substituted alkenes by treatment with hydrogen and a Chiral homogenous hydrogenation catalyst, the treatment of alkelydes & Ketones with Organo-Metallic compounds, in presence of achiral catalyst or solvent and the conversion to optically active of alkenes to epoxides H_2O & enzymes are also used.

$$ph—CH—MgCl + CH_2 == CHBr \xrightarrow[\text{Complex}]{\text{Chiral}} ph— CH—CH == CH_2$$
$$\qquad\quad | \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad |$$
$$\qquad\quad Me \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad Me$$
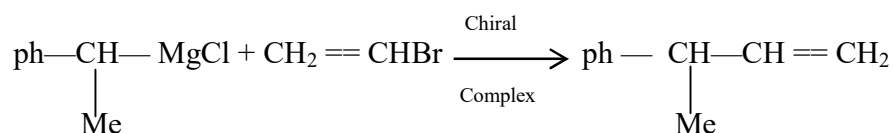
4. **Reaction in presence of Circularly Polarized Light -** The light used to initiate a photochemical reaction of a chiral reagent in circularly polarized light, and then a chiral product richer in one enantiomer might be obtained. In such cases the results are 1% only.

1.15 OPTICALLY ACTIVITY IN THE ABSENCE OF CHIRAL CARBON

Asymmetric carbon atom and its non-superimposibility are the basic concept of optically active compounds but some compounds are having no asymmetric _C' atom but are optically active (dissymmetric molecules).

Allenes exhibit optical isomerism provided the two groups attached to each terminal _C' atom are different.
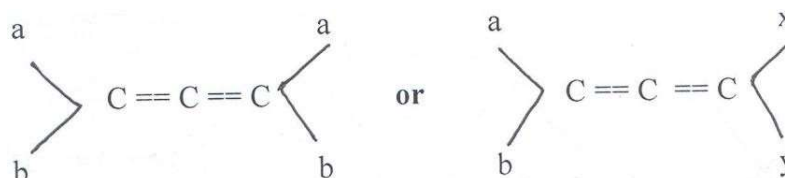
The optical isomerism in allenes was due to inhibition of free rotation of the groups attached to ethylenic _C' atoms and tetrahedral nature of these _C' atoms. The molecular orbital theory explains the optical isomerism in allenes. The d & l are the forms of 1, 3-di-a-naphthyle-1, 3-diphenyl allene (11) by the dehydration of 1, 3-di-a-naphthyl 3-diphenyl allyl alcohol (1) with the help of d& l camphor sulphonic acid respectively.
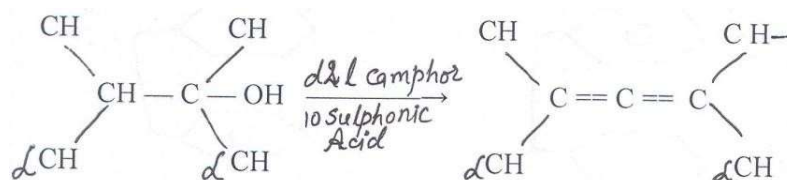
Spirans

When both the double bonds in allenes are replaced by rings, the resulting system is called Spiro Compounds or Spirans. The dissymmetry in spirans due to two rings perpendicular to each other with suitable substitution of the ends of system (a & b) or within rings will make molecule dissymmetric or optically active.
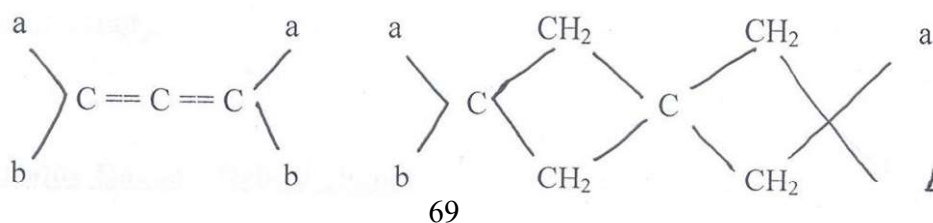
Allene   **Spirans**
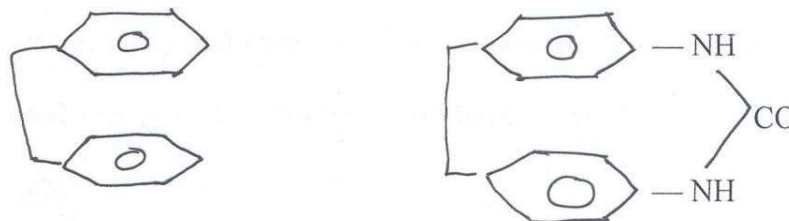
In Bi-phenyls, the optical isomerism is due to restricted rotation around the single bond between the two benzene nuclei of two forms and exhibit O, A.


The butterly structure of Bi-phenyl is obtained by condensation of benzidene with COCl.

Di-nitrodipheric acid was the first biphenyl compound to show optical isomerism. In biphenyl molecule, the two benzene nuclei are collinear and the introduction of bulky groups in the O-positions prevents free rotation of the nuclei about the co-axis and hence the two benzene nuclei in such substituted derivatives can not be co-planar i.e. the molecule is dissymmetric and shows optical activity.

Chirality Due to a Helical Shape

Many compounds have been prepared that are chiral because they have a shape that is actually helical and can, therefore, be left or right handed in orientation. The entire molecule is usually less than one full turn of the helix, but this does not alter the possibility of left and right handedness e.g. hexa-helicane, trans-cyclo octene. Heptalenes itself is not planner and its twisted structure makes it chiral but the enantiomers rapidly interconvert.

However, bulky and over crowding substituents can hinder the inter-conversion and several such compounds have been resolved.
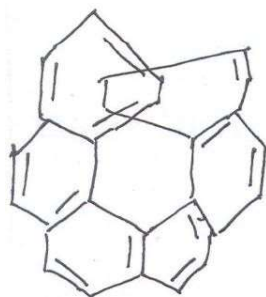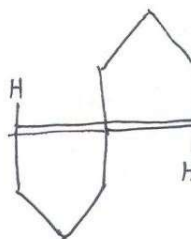
Hexahelicane   **Trans-cyclo-octene**

1.16   STEREOCHEMISTRY OF NITROGEN

After carbon compounds, the N_2 element also shows tetrahedral nature and like the carbonyl compounds, the Nitrogen compounds also show both the type of stereo-isomerism the optical and geometrical isomerism. The Nitrogen compounds must be non-planar and can be resolved and as soon as it attains planarity it becomes optically inactive. The Nitrogen can be trivalent or pentavalent, the compounds of both types N_2 atom have been resolved e.g. Amines, quaternary Ammonium Salts and Tertiary animes. Amines (Tertiary), the pyramidal inversion has observed in Nitrogen, Phosphorous and arsenic compounds. Sulphur owing to the configuration stability do not undergo pyramidal inversion and hence exhibit optical isomerism.

Quaternary Ammonium Salts

The asymmetric N_2 compounds should be capable of existing in two isomeric or enantiomeric forms e.g. allyl benzylmethyl phenyl Ammonium Iodide and many quaternary ammonium salts have been resolved.

$$CH_2 = CHCH_2 - \underset{\underset{C_6H_5}{|}}{\overset{\overset{CH_3}{|}}{N}} - \left[CH_2C_6H_5\right] \qquad \textbf{I}$$
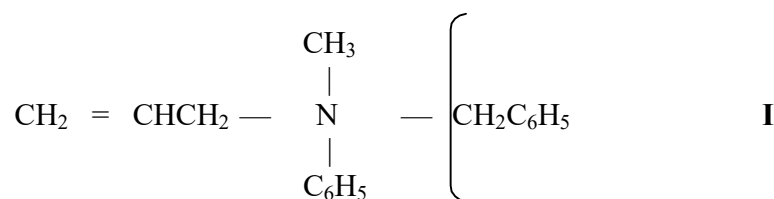
The Ammonium salt in optically active forms indicates that Ammonia ion cannot be planar and hence it may be either pyramidal or tetrahedral. Optically active Ammonium salts are very readily racemes as compared to that of ‗C' compounds.

Tertiary Amines, Oxides like quaternary Ammonium Salts, the tertiary amine oxides, having four different groups should also be resolvable ethylmethyl phenylamine oxide ‗I' was resolved.

$$C_2H_5 - \underset{\underset{C_6H_5}{}}{\overset{\overset{CH_3}{}}{N}} \longrightarrow O$$

$$C_6H_5 - \underset{\underset{CH_3}{|}}{\overset{\overset{|}{}}{N}} \longrightarrow O$$
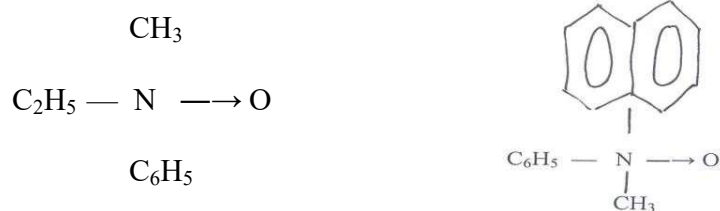
Geometrical Isomerism

The Nitrogen compounds can be exhibiting geometrical isomerism due to $C = N$ bond and $N = N$ bond e.g. oximes.
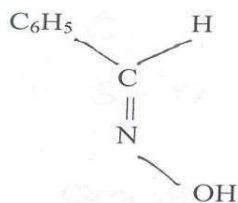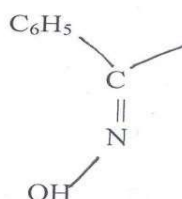
Cis or Syn.   **Trans or Antibenzoldoxime**

A nitrogen atom in a three-membered ring connected to an atom containing an unshared pair, for example, the two isomers of 1-chloro 2-methylaziridine (I and II) were separated and do not interconvert at room

trans   cis
I   II
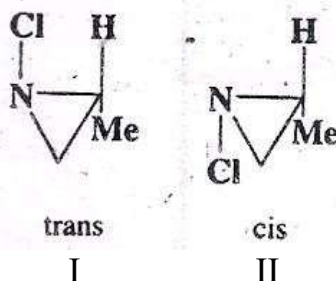
temperature. In suitable cases this barrier to inversion can result in compounds that are optically active solely because of a chiral tervalent nitrogen atom. For example, III is one of several chiral oxaziridines, both enantiomers of which have been prepared.

III   IV   V   VI
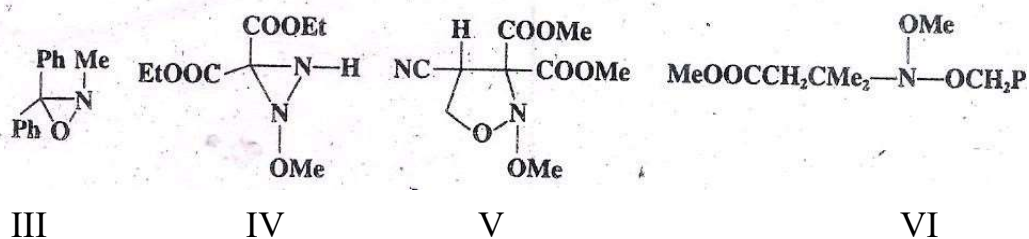
In this case too, the nitrogen is connected to an atom with an unshared pair. Conformational stability has also been demonstrated for diaziridines, e.g., IV and 1, 2-oxazolidines, e.g., V, even though in this case the ring is five-membered. However, note that the nitrogen atom in V is connected to two oxygen atoms.

$$\left[\begin{array}{c} {}^{16}O \\ {}^{17}O-P-OR \\ {}^{18}O \end{array} \right]^{2-}$$

IV
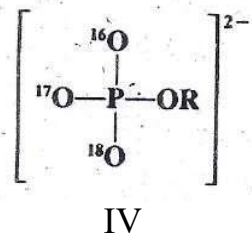
Another compound in which nitrogen is connected to two oxygens is VI. In this case there is no ring at all, but it has been resolved into (+) and (-) enantiomers ($[\alpha]_D^{20} \approx \pm 3°$).

1.17   STEREOCHEMISTRY OF SULPHUR

Various types of Sulphur compounds have been found resolvable i.e. optically active e.g. sulphonium salts, sulphoxides, sulphinic este, sulphidimines or sulphides.
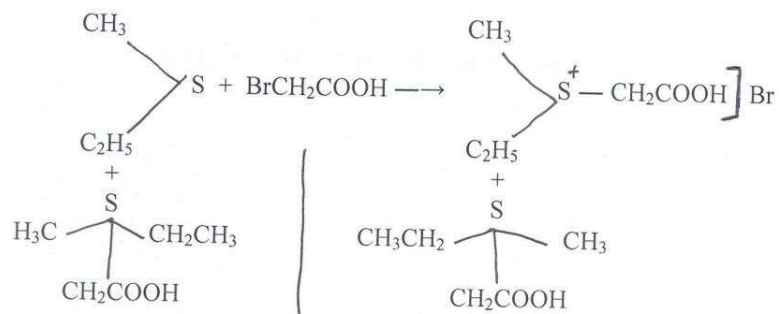
Enantiomers of carboxylmethyl sulphonium bromide can be resolved. Sulphinic estes were also resolved by kinetic method and also exhibit geometrical isomeric forms.
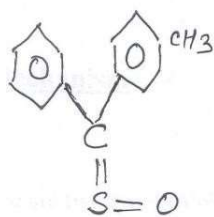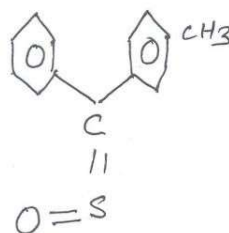
Cis or Syn   **Trans or Anti**

Sulfur exhibits
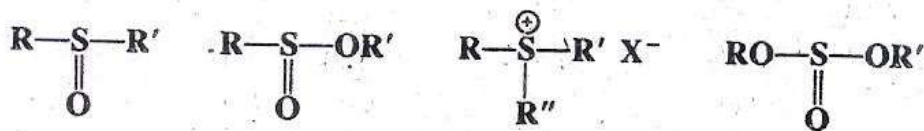
pyramidal bonding in sulfoxides, sulfinic esters, sulfonium salts, and sulfites. Examples of each of these have resolved been resolved.

I

1.18 STEREOCHEMISTRY OF PHOSPHORUS

Unlike tertiary amines, certain trivalent phosphorus compounds have been resolved due to slower frequency of oscillation. Thus the phosphine having large groups will have low oscillation frequency and hence can be resolved.

$$C_2H_5CH_3C_6H_5P, CH_3C_6H_5C_3H_7P \quad etc.$$

An interesting example is (+) $Ph^{12}CH_2SO^{13}CH_2Ph$, a sulfoxide in which the two alkyl groups differ only in ^{13}C versus ^{13}C but which has $[\alpha]_{280} = +0.71^o$. Phosphorous inverts more slowly and arsenic still more slowly. Nonbridgehead phosphorus, arsenic, and antimony compounds have also been resolved. This has even been done for phosphate esters that are chiral because the three oxygens are isotopically distinct.

LET US SUM UP

The bonding technology, like ionic, co-valent and co-ordinate and delocalized bonding, cross bonding with resonance, Aromaticity & Anti

and Homo aromaticity has been given. The Stereo-Chemistry of ‗C' and Chirality and Resolution of Stereo-Isomers, Geometric Isomerism has been explained.

CHECK YOUR PROGRESS – 1 THE KEY

a)   1.2.3   Hyper Conjugation

b)   1.5.1   Huckel Rule

c)   1.5.2   Anti-Aromaticity

CHECK YOUR PROGRESS – 2 THE KEY

d)   1.8   Stereo-Chemistry

e)   1.4   Tantomerism

f)   1.11.2 Methods of Resolution

* * *

important as the temperature increases, as is obvious from the equation

$\Delta G = \Delta H - T\Delta S$. The enthalpy term is independent of temperature, while the entropy term is directly proportional to the absolute temperature.

ΔH^*, the enthalpy of activation, is the difference in bond energies, including strain, resonance, and salvation energies, between the starting compounds and the transition state. In many reactions bonds have been broken or partially broken by the time the transition state is reached; the energy necessary for this is ΔH^*.

Entropy of activation ΔS^*, which is the difference in entropy between the starting compounds and the transition state, becomes important when two reacting molecules must approach each other in a specific orientation in order for the reaction to take place. For example, the reaction between a simple noncyclic alkyl chloride and hydroxide ion to give an alkene takes place only if, a simple noncyclic alkyl chloride and hydroxide ion to give an alkene takes place only if, in the transition

state, the reactants are oriented as shown. Not only must the OH^- should be near the chlorine atom or near R^1 or R^2, no reaction can take place. In order for a reaction to occur, the molecules must surrender the freedom they normally have to assume many possible arrangements in space and adopt only that one that leads to reaction. Thus, a considerable loss in entropy is involved, i.e., ΔS^* is negative.

2.0   KINETIC REQUIREMENTS FOR REACTION

As indicated in Thermodynamics a reaction having negative ΔG does not necessarily mean that will take place in a reasonable period of time. A negative ΔG is a necessary but not sufficient condition for a reaction to occur quickly. All activated complex go on to product at the same rate, so that the rate constant of the reaction depends only on the position of the equilibrium between the starting materials and the activated complex i.e. on K^* ΔG is related to K^* by $\Delta G + = - 2.3$ RT log K^* (K^* equilibrium constant) so that a higher value of ΔG^* (free energy activation) is associated with a smaller rate constt. The rate of reaction increases with rise in temperature as energy thus supplied helps the molecules to overcome the activation energy barrier. Some reaction leave no free energy of activation at all, meaning K^* is essentially infinite and that virtually all collisions lead to reaction, known as diffusion – controlled like ΔG, ΔG^* is made up of enthalpy and entropy components $\Delta G^* = \Delta H^* - T \Delta S^*$ (ΔH^* enthalpy and ΔS entropy of activation).

2.5.1 Kinetic & Thermodynamic Control

A compound under a given set of reaction conditions can undergo competing reactions to give different products. A free energy profile for a reaction in which _β' is thermodynamically more stable that C (lower Δ G) but C is formed faster (lower Δ G*). If neither reaction is reversible _C' will be formed in larger amount because it is formed faster. The product is kinetically controlled; and if the reaction is permitted to approach – equilibrium, the predominant or even exclusive product will be β. Under these conditions, the C, first formed reverts to a, while the more stable β does so much less, the product is thermodynamically controlled.

2.1   HAMMOND PASTULATE

This states that for any single reaction step, the Geometry of the transition state for that step resemble the side to which it is closer in free energy. The postulate is more useful in dealing with reactions with intermediate.

Since transition states have zero lifetimes, it is impossible to observe them directly and information about their geometries must be obtained from inference. In some cases our inferences can be strong. For example, in the S_N2 reaction between CH_3I and I^- (a reaction in which product is identical to the starting compound), the transition state should be perfectly symmetric. In most cases, however, we cannot reach such easy

conclusions, and we are greatly aided by Hammond postulate,[10] which states that for any single reaction step, the geometry of the transition state for that step resembles the side to which it is close in free energy. Thus, for an exothermal reaction, the transition state resembles the reactants more than products, though not much more because there is a substantial ΔG^* on both sides. The postulate is most useful in dealing with reactions and to many functional groups and correlates quite well an enormous amount of data.

2.6.1 Hammett Equation

The structural change affects the acidic and basic properties in a qualitative manner. Thus a subsitituent can function as neighboring group as electron donor or acceptor by resonance and inductive effects or can alternatively cause steric effects. The relative reactivity of a molecule by making modest changes in their structures and in a more quantitative manner is Hammett concept.

The Hammett equation has also been shown to apply to many physical measurements, including ir frequencies and nmr chemical shifts. The treatment is reasonably successful whether the substrates are attacked by electrophilic, nucleophilic, or free-radical reagents, the important thing being that the mechanism be the same within a given reaction series. Hammett set up the equation :

$$\log\frac{k}{k_0}=\sigma\rho$$

where k_0 is the rate constant or equilibrium constant for X = H, k is the constant for the group X, ρ is a constant for a given reaction under a given set of conditions, and σ is a constant characteristic of the group X. the equation is called the Hammett equation.

2.2   METHODS OF DETERMINATION OF MECHANISM

There are several methods for determining mechanism of reaction and formation of products firstly identification of products, the reaction proposed must account for product required and hence isolation of intermediate and its detection, then trapping of intermediate as suspected will make the formation of products possible.
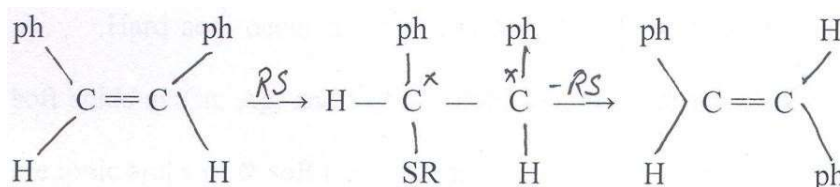
In the above case of isotopic labelling we have made an assumption that properties of the compounds are not qualitatively

changed when an isotope is substituted for an atom. In spite of their chemical similarity, the isotopes are not exactly identical and often the rate at which chemical reactions occur may vary with isotope. This variation in the rate of a reaction due to difference in the isotope present in the molecule is called the isotope effect, and it is usually small.

Check your progress – 1

Notes :- 1. Write your answers in the space given below.

                2. Compare your answers with those given at the end.

a) 2.3.3 Elimination Reactions   b) 2.6.1 Hammett Equation

c) 2.8   Structure Stability   d) 2.11   Allylic Halogenation

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2.7.1 Isotope Effects

When H_2 in a reactant molecule is replaced by deuterium, there is often a change in the rate such changes are known as deuterium isotope effects and are expressed by the ratio $K_H K_D$. It was found that deuterium isotope effects usually range from 1 (no. of isotope effect at all) to about 7 or 8, though in a few cases larger and smaller values have been reported.

2.7.2 Hard & Soft Acids And Bases

Soft Lewis bases are those in which the donor atoms are usually easily polarized and have low electro-negativity and Hard Lewis bases are those in which the donor atoms have low polarisability and high electro-negativity.

$$Ag+ \quad + \quad 2\,I^- \quad \longrightarrow \quad Ag^-\,I^2$$

Soft Acid   **Soft Base**   **Stable complex**

$$Ag+ \quad + \quad 2\,F \quad \longrightarrow \quad AgF_2$$

Soft Acid   **Hard Base**   **Unstable complex**

Hard acid occur in nature as Mg, Ca, Al as CO_3 and oxides, soft acids as Cu, Ag, and Hg as sulphides. Hard & hard interactions are ionic and soft & soft is co-valent.

2.3 STRUCTURE, STABILITY & REACTIVITY OF CARBOCATIONS, FREE RADICAL, CARBENES AND NITRENES

The above factor's like structure, stability and reactivity depend on three important reaction intermediates like carbonations or carbonium ions, carbonious free radicals which then react with the reagent to form the products.

2.8.1 Carbonium Ions Or Carbocations

From hetrolytic fission, the carbonium ions are positively charged containing a _C' atom having only six electrons in three bonds, the carbon atom lacks a pair of electrons in its valency shell. In carbonium ions, the positive _C' is called the carbonium and names of the bonded group are adjoined as a prefix, in cat ion. Cat

ion system is used frequently. They are primary, secondary and tertiary but these are short lived but rearrangement makes:

$$H - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} + CH_3 - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} + CH_3 - \overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}} + CH_3 - \overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}$$
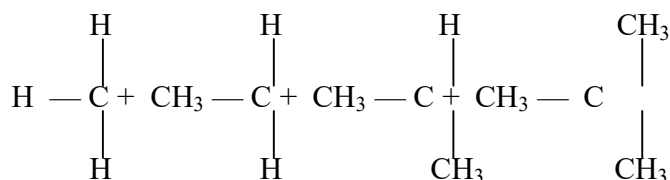
Stable

2.8.2 Carbon Ions

When certain organic compounds treated with strong Lewis bases lose a _H$_2$' atom from a C-H bond, as proton and thus form anionic species called carbon-ions. Thus carbon-ions are negatively charged species, containing a _C' atom with three bonds are an unshared pair of electrons.

$$(C_6H_5)_3 \ CH \xrightleftharpoons{\quad Base \quad} (C_6H_5)_3 \ C^{(-)}$$

**Triphenyl Methane**   **Triphenyl Carbon-ion**
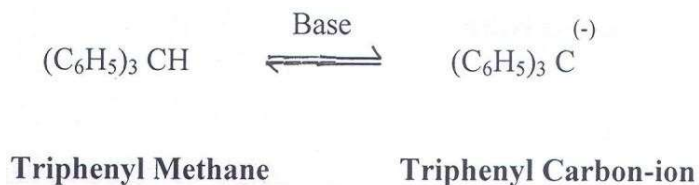
These carbon ions are two types, stable and transient.

2.8.3 Free Radical

The odd and unpaired electrons are called as free radical in any species of organic molecules. Electrically they are neutral because of the presence of odd electrons. They are (free radicals) in constant search of another electron to pair up and hence they are highly reactive species.

2.8.4 Carbenes

The transitory reaction intermediate called Carbenes or Methylenes are divalent carbon species containing two unpaired electrons, are formed by homolytic fission. They are electron deficient, having only six electrons in the outer shell of _C' atom, but it possesses no charge. Hence they are neutral species.

$$H : \overset{\overset{\displaystyle H}{\cdot \cdot}}{C} : \qquad RCHN_2 \xrightarrow{\text{pyrolysis}} RCH : + N_2$$
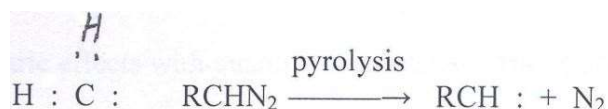
Alkyl carbon

Carbenes are highly reactive species, practically all having lifetimes considerably under 1 sec. Carbenes have been isolated only by/ entrapment in matrices at low temperatures (77 K or less).

The parent species CH_2 is usually called methylene, although derivatives are more often named by the carbene nomenclature. Thus CCl_2 is generally known as dichlorocarbene, though it can also be called dichloromethylene.

The two bonded electrons of a carbene may be either paired or unpaired. If they are paired, the species is spectrally a singlet, while, as we have seen, two unpaired electrons appear as a triplet. An ingenious method of distinguishing between the two possibilities was developed by Skell, based on the common reaction to addition of carbenes to double bonds to form cyclopropane derivatives. If the singlet species adds to cis-2-butene, the resulting cyclopropane should be the cis isomer since the

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movements of the two pairs of electrons should occur either simultaneously or with one rapidly succeeding another.

However, if the attack is by a triplet species, the two unpaired electrons cannot both go into a new covalent bond, since by Hund's rule they have parellel spins.
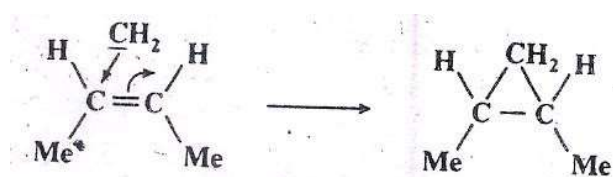
2.8.5 Nitrenes Or Imidogens

Nitrogen analogues of carbenes, the nitrenes R –N may be electron deficient species in which Nitrogen has a sexlet of electrons. The parent nitrene, NH singlet or NH triplet are found in sun and in atmosphere of Jupiter.

$$NH_3 \xrightarrow{\ hv\ } N_2 \ + \ HN \xrightarrow[\text{Nitrene}]{\ C_6H_5CH_3\ } H_2N \ - \ C_6H_4 – CH_3 \ - \ P$$
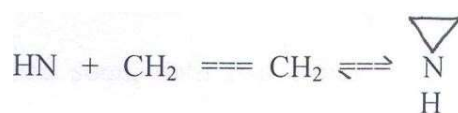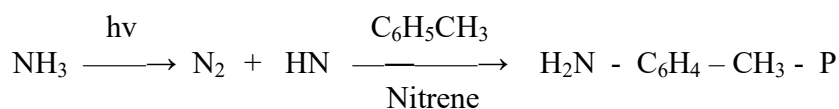
Nitrenes, R – N, are the nitrogen analogs of carbenes, and most of what we have said about carbenes also applies to them. Nitrenes are too reactive for isolation under ordinary conditions. Alkyl nitrenes have been isolated by trapping

in matrices at 4 K, while aryl nitrenes, which are less reactive, can be trapped at 77 K. The ground state of NH, and probably of

$$R - \overline{\underline{N}} \qquad\qquad R - \overline{N} \bullet$$
$$\bullet$$

most nitrenes, is a triplet, though nitrenes can be generated in both triplet and singlet states. In additions of EtOOC – N to C = C double bonds two species are involved, one of which adds stereospecifically and the other not. By analogy with Skell's proposal involving carbenes these are taken to be the singlet and triplet species, respectively.

The two principal means of generating nitrenes are analogues to those used to form carbenes.

$$RCOOAg + Br_2 \rightarrow RBr + CO_2 + AgBr$$

Direct method of introducing N_2 atom in many molecules.

2.4   EFFECT OF STRUCTURE REACTIVITY

The effect of structure reactivity has greatest variations and compounds leaving same group may react in different ways, some slowly and some fast depending on position of equilibrium, field effect and stearic effects with quantity of reactants. The relationship of these components effects reaction activity.

2.9.1 Free Radical Reactions

This consists of two steps atleast. The first involves formation of free radicals i.e. hemolytic cleavage of bond having each fragment retains one electron, as initiation step, may be slow or fast due to induced heat, liglet depending on the type of bond. Second step involves the destruction of free radicals, may be due to like or unlike bonds or radicals to form a new bond, known as termination step, may be slow or fast according to available species. The newly formed radical can react with another molecule and produce another radical and soon, until two radicals do meet each other and terminate the sequence known as propagation, the process is chain reaction.

2.9.2 The characteristics of free radical reactions

The reactions are similar, whether in liquid or vapour state. They are not affected by acid and base or change in polarity, non-polar solvents may suppress ionic reaction. They are initiated or accelerated by typical free-radical sources. Their rates are decreased or the reactions are suppressed entirely. The substances that seavenge free radicals e.g. Nitric-oxide, O_2, are known as inhibitors.

In a free radical substitution reaction R –X ▯ R – Y, R – X ▯ R°+ X°, there must be a cleavage of the substrate RX, so that R, radical are produced, only on spontaneous cleavage R – X ▯ R° + X°, caused by heat or light but R is produced by abstraction – R – X + W ▯ R° + WX$_{(5)}$ W° is produced by adding a compound, as peroxide and quickly forms free radicals, are know as initiator once R is formed, it can go to product in two ways by abstraction. R° + Y – W ▯ R – Y + W°$_{(4)}$ by coupling with

another radical R° + Y° ⎕ R – Y. In moderately long chain much more products will be produced due to abstraction, by coupling, cleavage steps, like $_{(3)}$ & $_{(4)}$. The polar character in transition state is also obeys.

2.5   MECHANISM AT AN AROMATIC, SUBSTRATE

The above mechanism can not account for all reactions of aromatic substrates e.g.

Ar° + ArH ⎕ Ar - Ar

The coupling of two rings can not be simple abstraction – since, abstraction of an entire group such as phenyl by a free radical is very unlikely.

Ar° + ArH ⎕ Ar - Ar + H°

The product can be explained by the mechanism similar to electrophilic and nucleophilic aromatic substitution.

In first step, the radical attacks the ring as an electrophilic or a nucleophilic. The intermediate is stable because of resonance. It can terminate in three ways by simple
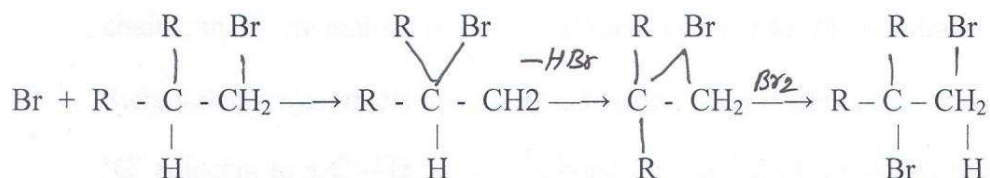

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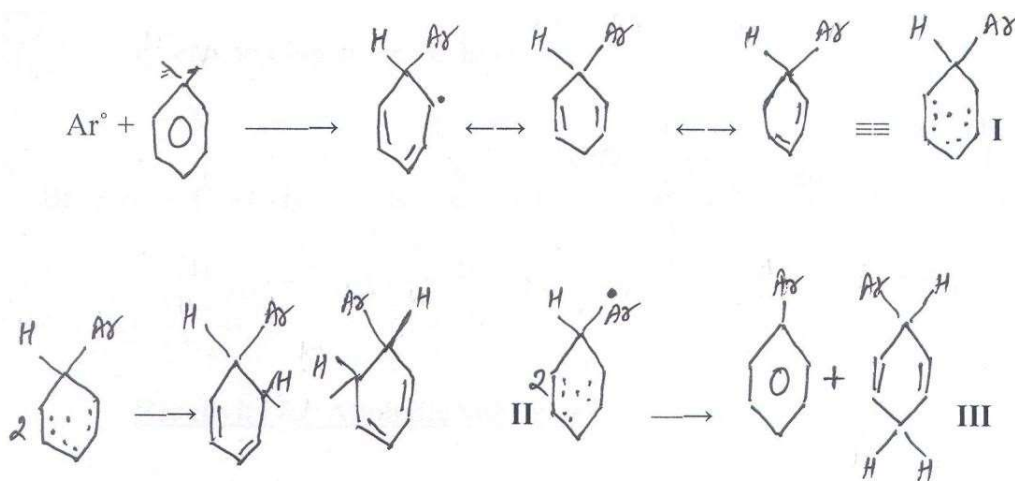
coupling or by disproportionation or if a species _R' is present which abstracts H_2 by abstraction.
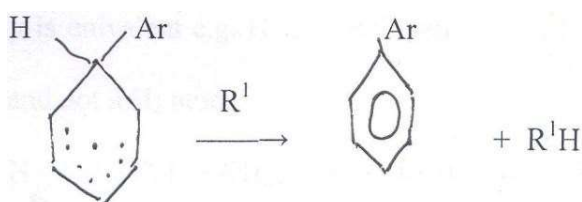
Dehydrophenyl to biphenyl – III

2.10.1   Neighboring Group Assistance In Free Radical Reactions

The cleavage steps and abstraction steps have been accelerated by the presence of neighbouring groups as in II & III shown above. Bromination of alkyl bromides gave

80 to 94% substitution of _C' adjacent to bromine already in the molecule. The position close to polar group e.g. bromine should actually deactivated by electron-withdrawing field effect of the bromine. The abstraction is assisted by a neighbouring group i.e. Br_2 atom.

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2.10.2 Reactivity for Aliphatic Substrates

In chain reaction the steps that determines what the product will be most often an abstraction step, what is abstracted by a free radical is almost never a tetra or trivalent atom and seldom a divalent one only is univalent e.g. H_2 and Halogen. The ethane gives an ethyl radical and not a H_2 atom.

$$H - Cl + CH_3 + CH_2 \triangle H = 3 \; Kcal/mole - 13 \; K \; \text{--}/Mole$$

$$CH_3 \; CH_3 + Cl$$

$$CH_3CH_2 - Cl + H \cdot \triangle H \quad + 18 \; K \; Cal/mole. + 76 \; KJ/mol$$
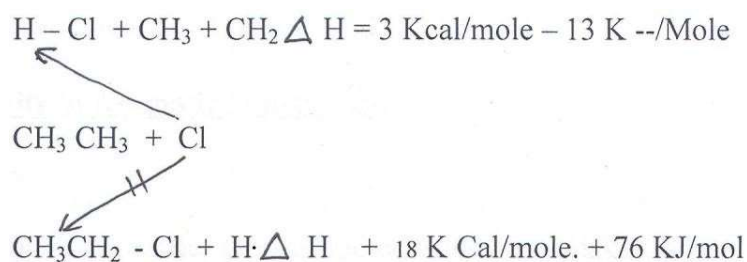
The reason is stearic effect. A univalent atom is more exposed to attach by the incoming radical than an atom with a higher valence, another reason is abstraction of univalent atom H_2 as leaving atom and Cl_2 as abstracting species have been studied. Alkanes, olefins and alkyl side chains are of aromatic rings. In Alkanes, the tertiary H_2 are abstracted by any radical and in olefins, the substrate molecule contains double bond and gives addition reaction only. In Alkyl side chains, many anomalous results have been reported for the substrates. Stereo-electronic effects are important, when a H_2 is abstracted from _C' adjacent to a C – O or C – N bond abstraction of a halogen has been in order of RI > RB > RCl > RF.

2.10.3   Reactivity of Bridgehead

Many free-radical reactions have been observed at bridgehead Carbons i.e. free radical need not be planner. The bridgehead free radical substitution is possible but not preferred because of strain involved.
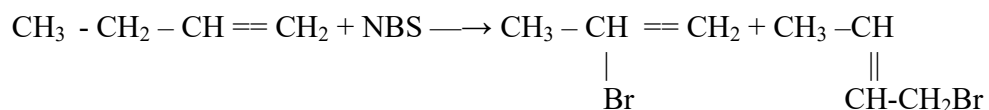
2.10.4   Reactivity in Aromatic Substitution

In an Aromatic _C', free radical substitution takes place, when H_2 is abstracted to give an aryl radical only know the position of attack to give intermediate. The ortho position is much reactive than para. All substitution increase reactivity in ortho & para in benzene. The reactivity of meta is the same. Stearic effect may decrease reactivity at para position, due to large groups. Electron donating groups are having less effect than electron withdrawing groups. The substituents have less effect than in electrophilic or nucleophitic substitution and hence rate factor is not great.

2.10.5 Reactivity of Attacking Radical and the Effect of Solvent in reactivity
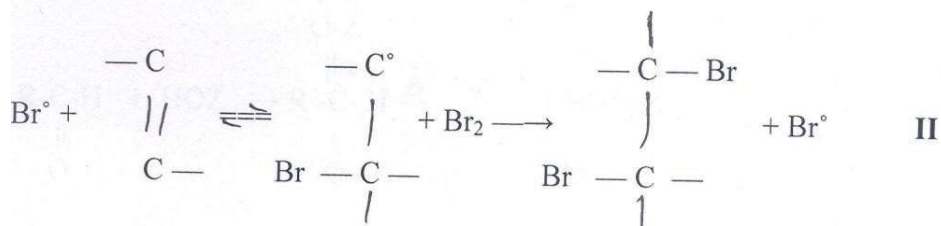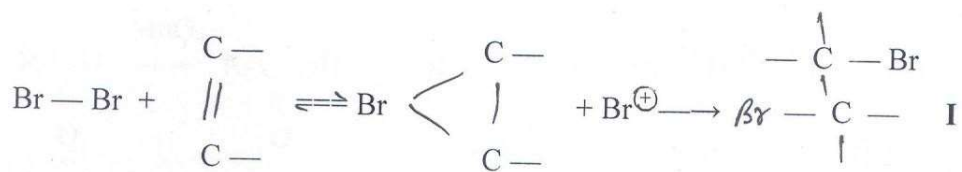
Some free radicals are much chooser than others. Br_2 shows greater tendency than Cl_2 to attack, as C – H bond is weaker at δ position. The solvent has little effect on free radical substitution in comparison to ionic one. Similar is with gas phase. The Aromatic solvent makes little difference.

2.6   ALLYLLIC HALOGENATION

Olefins can be halogenated in the allylic positions by no. of reagents, of which N-Bromosuccinimide is by far most common. Halogenation means Halo-De-Hydrogenation called Wohl-Ziegler Bromination. The reactin at allylic position is quite specific and gives good yield. However, when Allylic radical intermediate is unsymmetrical, Allylic rearrangements can take place and mixture of both products is obtained.

$$CH_3 - CH_2 - CH == CH_2 + NBS \longrightarrow CH_3 - \underset{\underset{Br}{|}}{CH} == CH_2 + CH_3 - \underset{\underset{CH-CH_2Br}{\|}}{CH}$$
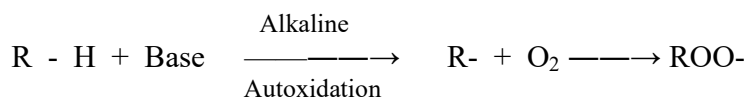
The mechanism of Allylic Bromination is of the free radical type as given by given by Dauben & Mecoy. In bromination of double bond, one atom of an attacking Br molecule becomes attached to the substrat, whether the addition is electrophilic or free radical.

(Allylic Chlorination also takes place with N-Chlorosuccinimide and orylselenyl Chloide as catalyst.)

2.7 OXIDATION OF ALDEHYDES TO CARBOXYLIC ACIDS

It is most common reaction in Organic Chemistry, in presence of Oxidizing agents, like KMnO$_4$, chromic acid in any medium, acid, base or neutral. In oxidation of aldehydes, there are two types of a free-radical mechanism and an ionic one. In free radical process, the aldehydic _H$_2$' is abstracted to leave all acyl radical, which obtains OH from oxidizing agent but in ionic, the addition of a species OZ to the carbonyl bond to give a alkaline solution and in acid or neutral solution. The aldehylic _H$_2$' of A & B is then lost as a proton to a base, while Z leaves with its electron pair.

$$R-\overset{||}{\underset{O}{C}}-H \xrightarrow{MnO_4} R-\overset{||}{\underset{O}{C}}-OH$$

$$R-\overset{||}{\underset{\underline{O}}{C}}-H + OZ \rightarrow R-\overset{O-Z}{\underset{\underline{O}}{\overset{||}{C}}}-H \xrightarrow{\beta} R-e + BH + Z^- \quad A$$

$$R-\overset{||}{\underset{O}{C}}-H + HOZ \rightarrow R-\overset{O-Z}{\underset{O-H}{\overset{||}{C}}}-H \xrightarrow{\beta^-} R-e + BH + Z^- \quad B$$

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2.12.1 Auto-oxidation

The atmospheric oxidation (slow) of C-H to COOH is called Antoxidation. The reaction takes places, when compounds are allowed to stand in open air and is catalyst by light. The Hydro-peroxide produced often reacts further to give alcohols, Ketones. The useful application is drying of paints and varnishes in auto-oxidation in atmosphere. The Hydro-peroxides are explosive and are dangerous for storage. Oxygen (di-radical) does not react and abstract $\_H2'$, but if traces of free radicals are produced by initiating process, it reacts with $\_O_2'$ to give R- O – O, since this type of radical does abstract $\_H_2'$. The chain is –

$$R'OO – RH \rightarrow RO + R'OOH, \ RO + O_2 \rightarrow R - OO°$$

$$R - H + Base \xrightarrow[\text{Autoxidation}]{\text{Alkaline}} R- + O_2 \longrightarrow ROO-$$

Free radical reaction gives optically inactive products because of plane of symmetry.

2.8　　　COUPLING OF ALKYNES

In De-hydrogen – coupling, the terminal alkynes can be coupled by heating with stoichiometric amount of cupric salts pyridine or any base. The reaction produces symmetrical diynes called eglinton reaction –
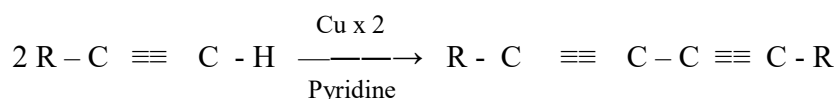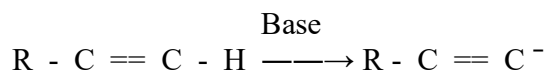
$$2 \ R – C \equiv C - H \xrightarrow[\text{Pyridine}]{\text{Cu x 2}} R - C \equiv C – C \equiv C - R$$

This reaction is of wide range. The oxidation is specific for triple bond H_2. The mechanism of the **Eglinton & Glaser reaction** begins with loss of a proton, there is a base present and Acetylenic protons are acidic.

$$\text{R - C} == \text{C - H} \xrightarrow{\text{Base}} \text{R - C} == \text{C}^-$$

The last step is coupling of two radicals.

$$2\,\text{R - C} == \text{C}° \longrightarrow \text{R - C} == \text{C} - \text{C} == \text{C} - \text{R}$$
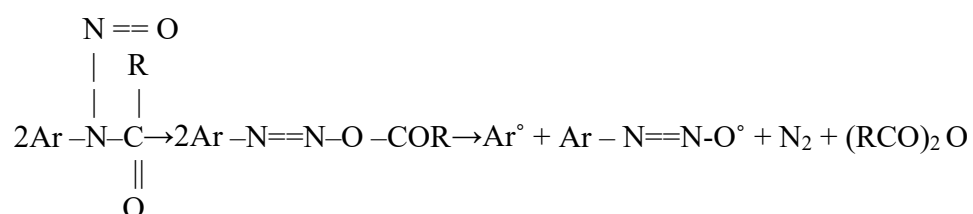
2.9 ARYLATION OF AROMATIC COMPOUNDS BY DIAZONIUM SALTS

Aryl-de-hydrogenation or Arylation, normally in acidic solution of diazomium salt is made alkaline, Aryl portion of diazonium salt can couple with another aromatic ring, called Gomberg reaction. The yield is not high (40%) because of many side reactions by diazonium.
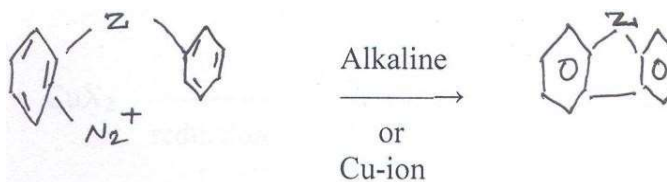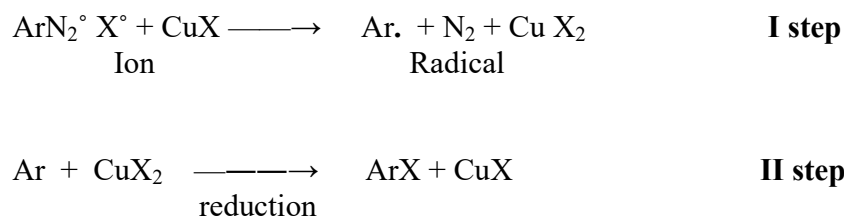
Other compounds with $N_2 - N_2$ bonds are used in place of diazonium salts e.g. N-nitro-so amides, thus generation of Aryl radical from a co-valent compound. In acid solution diazonium salts are ionic and their reactions are polar, they cleave the product is an aryl cation. The aryl radical thus formed attacks the subtrate to give the intermediate, which the radical substrates 'H$_2$' to give the product.
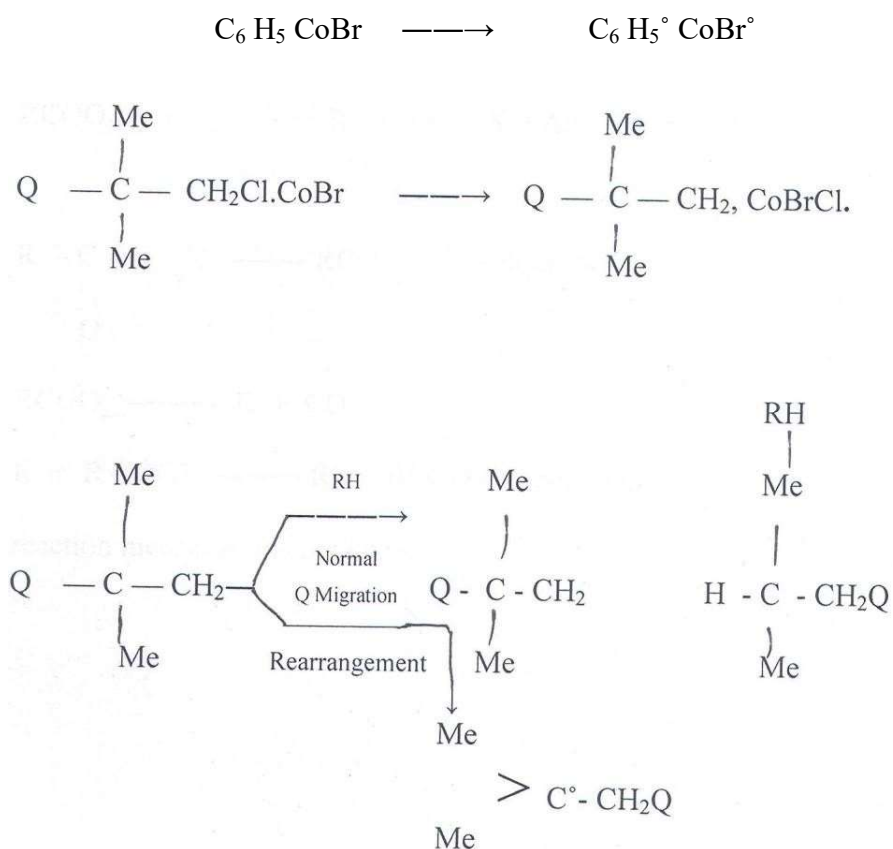
$$2Ar-N-C \rightarrow 2Ar-N==N-O-COR \rightarrow Ar° + Ar-N==N-O° + N_2 + (RCO)_2O$$

(with structure showing N==O, R, and O groups attached)

2.14.1 Sandmeyer Reaction

The process of Chloro-de-diazonium or replacement of the Diazonium group by Cl_2 or Br_2 . The treatment of diazonium salts with cuprous chloride or bromide leads to aryl chlorides or bromides, respectively. The reaction is called **Sandmeyer Reaction**, with Cu & HBr or Hcl called **Gatterman reaction** used for introducing Br_2 or Cl_2 in Aromatic rings.

$$ArN_2° \ X° + CuX \longrightarrow Ar. + N_2 + Cu \ X_2 \qquad \textbf{I step}$$
$$\text{Ion} \qquad\qquad\qquad \text{Radical}$$

$$Ar + CuX_2 \xrightarrow{\text{reduction}} ArX + CuX \qquad \textbf{II step}$$
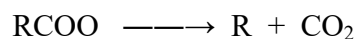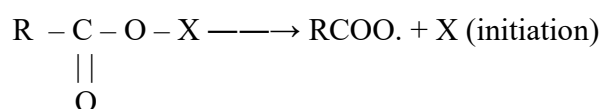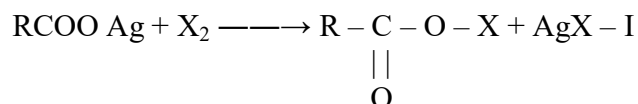
2.14.2 Free Radical Rearrangements

Free Radicals, compared to many other electrons deficient, show less tendencies to undergo rearrangements. The largest numbers of radicals rearranged now are those in which an aryl group migrates to an adjacent position. In cyclic compounds, the migration of a phenyl group was reported but not in details. For aryl migration, additional resonance structures are available for the delocalization of the odd electrons, thus stabilization is possible. The phenyl migration was observed in 1Chloro-2-Methyl-2Phenyl Propane, with phenyl Magnesium Bromide, in presence of Cobaltous Bromide.

$$C_6 H_5 CoBr \longrightarrow C_6 H_5^{\circ} CoBr^{\circ}$$

$$Q - \overset{\overset{\displaystyle Me}{|}}{\underset{\underset{\displaystyle Me}{|}}{C}} - CH_2Cl.CoBr \longrightarrow Q - \overset{\overset{\displaystyle Me}{|}}{\underset{\underset{\displaystyle Me}{|}}{C}} - CH_2, CoBrCl.$$

No unambiguous case of an alkyl or H_2 migration is yet known in simple radicals. The migration of an alkyl group in carbocations is frequently observed, but free radicals shows no tendency to rearrange.

2.10   HUNDSDIECKER REACTION

The Brome-de-carboxylation – The reaction of silver salt of Carboxylic acid with Br_2 is called **Hunds Reaction**. This gives good result for n-Alkyl R from 2 to 18 carbons and for many-branched R to producing primary, secondary and tertiary bromides.   I step – no free radical formation and the reaction mechanism is not known.

$$RCOO\,Ag + X_2 \longrightarrow R - \underset{\underset{O}{||}}{C} - O - X + AgX - I$$

$$R - \underset{\underset{O}{||}}{C} - O - X \longrightarrow RCOO. + X \text{ (initiation)}$$

$$RCOO\_ \longrightarrow R + CO_2$$

$$R + R\,COOX \longrightarrow RX + RCOO \text{ (Propagation)}$$

Many functional groups may be present as long as they are not α-substituted. R may also be aryl. However, if R contains unsaturation, the reaction seldom gives good results. Although bromine is the most often used halogen, chlorine and iodine have also been used.

The first step is not a free-radical process and its actual mechanism is not known. 21 is an acyl hypohalite and is presumed to be an intermediate, although it has never been isolated from the reaction mixture. Among the evidence for the mechanism is that optical activity at R is lost (except when a neighboring bromine atom is present; if R is neopentyl, there is no rearrangement, which would certainly happen with a carbocation; and the side products, notably R – R, are consistent with a free-radical mechanism.

$$RCOOAg + Br_2 \rightarrow RBr + CO_2 + AgBr$$

LET US SUM UP

The various types of reaction mechanisms, Homolytic, Hetrolytic & types of reaction, addition, substitution, Elimination and rearrangement has been explained. Thermodynamic & Kinetic controls and various name reaction of the same has been given. Methods of mechanism, structure stability etc. Carbocation and free radical has been explained. Oxidation, Isotopic and Auto-oxidation has been explained.

CHECK YOUR PROGRESS – 1 – THE KEY

a) 2.3.3 Elimination

b) 2.6.1 Hammit

c) 2.8   Structure

d) 2.11   Allylic

CHECK YOUR PROGRESS – 2 – THE KEY

a) 2.11   Homolytic & Heterolytic

b) 2.2   Homolytic & Heterolytic

c) 2.6   Hammod Pastulate

d) 2.8   Structure, Stability & Reactivity

e) 2.9   Structure Reactivity

f) 2.13   Coupling

* * *

M.Sc. (Previous) Chemistry

Paper – II
(Organic Chemistry)

Block – II

Unit – III
Aliphatic Nucleophilic substitutions

Unit – IV
Addition to Carbon-Carbon Multiple Bonds

Unit – V
Pericyclic Reactions

*Author : PROF. M.P. AGNIHOTRI,*M.Sc. Ph.D.

UNIT–III : ALIPHATIC NUCLEOPHILIC SUBSTITUTIONS

Structure

3.0 INTRODUCTION

The discovery of electronic concept and the electron shifting, substitution and rearrangements, disclosed various reaction mechanism by various scientists like Vilsemeir, Von-Richer, Smiles & Sommelet etc., which gave substantial viable structures to various organic compounds and their by also explained reaction mechanism.

3.1   OBJECTIVE

The various reactions of Aliphatic & Aromatic (Neucleophilic) with substitutions and additions are very specific t the mode of various bonds and functional groups, whether electron donating or releasing. This Chapter deals with it.

3.2   SUBSTITUTION AS DISPLACEMENT REACTION

The process involves replacement of an atom or group by another atom or group. In this, the breaking of bond with covalent compounds and formation of a new bond between the two substituted compounds, the process may take place in three ways –

**Homolytic, Heterolytic & Heterolysis**.

In **Homolytic fission** occurs at high temperature and the substitution reaction proceeds through free radical formation, as free radical substitution e.g.

$$CH_3 - CH == CH_2 \quad \xrightarrow[400°-500°]{Cl_2} \quad CH_2Cl\ CH == CH_2 + Hcl$$
$$\text{Propane}$$
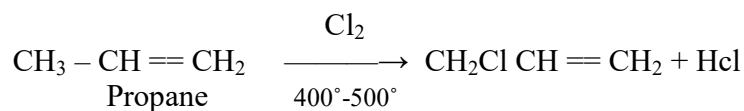
and in **Heterolytic fission** occurs when the reagent is an electrophilic and it will attach the atom or group having more electrons i.e. electrophilic substitution e.g.

$$C_6H_5H + NO_3 \quad \longrightarrow \quad C_6H_5NO_2 + H^-$$

In **Heterolysis fission** occurs when reagent is nucleophilic (anionic) or electron supplier and will attack the atom or group having low electron density e.g.

$$RCl + {}^-OH \quad \longrightarrow \quad R - OH + Cl^-$$
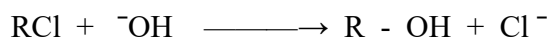
The nucleophilic substitution need not necessarily be a negatively charged. It may be electrically neutral but it must possess unshared electrons to be donated to an attacking nucleus e.g. Trialkyl-amine is electrically neutral but posses a pair of elelctron and act as nucleophilic reagent. The nucleophilic reactions or substitution take place by uni-molecular and bio-molecular.

The rate of reaction is proportional to the concentration of free radical alkyl halide is said to be uni-molecular mechanism called uni-molecular nucleophilic substitution reaction N on the other hand, if the rate of reaction is proportional to the concentration of the alkyl-halide as well as the base, the reaction follows bi-molecular mechanism. The bi-molecular mechanism involves one step. The nucleophilic reagent donates its electrons pair to the group and simultaneous the group or atom accepts the electrons paid and transition state obtained. Both reagents are involved in the covalency changed and hence the mechanism is bi-molecular acid represented as SN^2 e.g.

$CH_2 - Br + OH^- \longrightarrow HO -- CH_2 -- Br \longrightarrow OH - CH_3 + Br^-$
 Alkyl halide   Hydrolysis   Transition State
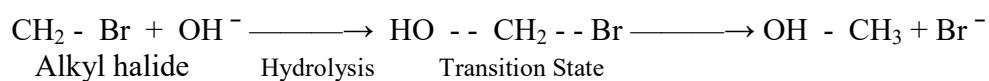
In set mechanism, certain nucleophilic substitution reaction involves radical or radical ions in which first step is the transfer of an electron from nucleophilic to the substrate to form a radical anion e.g. $R - X + Y - \longrightarrow RX + Y$, it is single electron transfer mechanism i.e. Set Mechanism and follow SN^2 Mechanism e.g.

$Y^- + R - X \longrightarrow [YR - X -] \longrightarrow YRX^- \longrightarrow Y - R + X$
                        Transition State
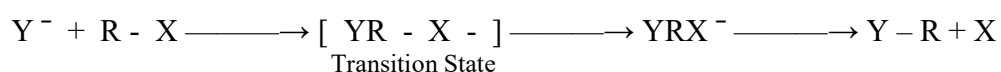
3.2.1 Neighboring groups Mechanism

In this rate of reaction is greater than expected and configurationat a Chirat Carbon is retained and not inverted or racemized. These cases, there is group with an unshared pair of electron to the leaving group. The operation is called **neighbouring group mechanism** and consists of essentially of two SN² substitution each causing an inversion, so the net result is retension of configuration. In the first step the neighbouring group acts as nucleophilic pushing out the leaving group but still retaining attachment to the molecule and in second step the external nucleophic displaces the neighbouring group by a backside attack.

In the neighbouring group participation by π and δ bond, the nucleophilic attack is made by an atom with an unshared pair of electrons. Neighbouring group participation by $C == C\ \pi$ bonds are $C - C$ and $C - H\ \delta$ bonds. The neighbouring
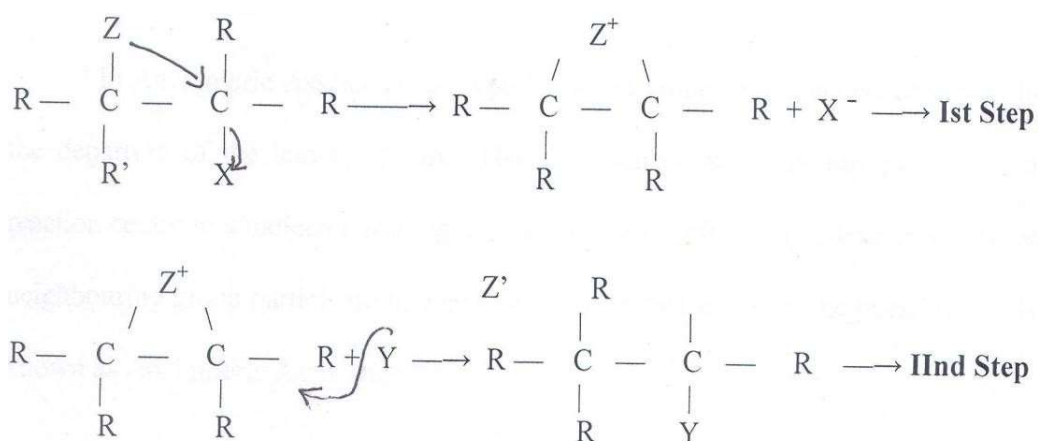
Group Z attacks faster than Y e.g. dl pair of 3-bromo-2-butanol when treated with HBr gave dl-2, 3 dibromo-butane. These intermediates are called non-classical carbocations. In Classical Carbocations, the positive charge is localized or one _C'

atom or delocalized by resonance involving an unshared pair of electrons or a double or triple bond in allylic position. In non-classical carbocation, the positive charge is delocalized by a double or triple bond. The is not in the allylic position or by a single bond e.g. 7-norbornylcation. The norbornyl cation II and the cyclopropyrl methyl cation III is called hemolytic carbocation.
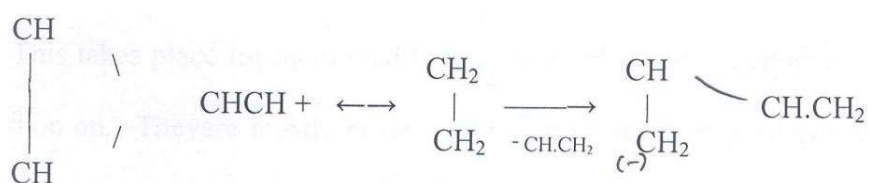
The first is called the δ route to a non-classical carbocation because participation of a δ bond involved, the second is called the π route.

In Anchimeric Assistance, a properly placed group in a molecule can assist in the departure of the leaving group. The involvement of a function group with a reaction centre in a molecule leading to reaction via a cyclic intermediate is known as neighbouring group participation, which results in increase in rate, the phenomenon is known as Anchimeric Assistance.

In classical and non-classical carbocation, the carbonize ions are stabilized by the movement of either a long pair of electron or π electrons in conjugation to the positively charged _C' atom to form a new bond, such carbonium ions are called classical carbonium ions. The formation of classical carbonium ions does not explain some reactions, thus canonical forms involving the movement of a pair of electrons or

even δ electron form a new δ bond, the carbonium ion intermediates formed called non-classical _C' ions.

3.2.2 Carbocation Rearrangements

This takes place for more readily than those of involving either a free radical or a carbonion. Theyare mostly occur, when normal reaction produces an unstable ion, which can be converted to a more stable one e.g. pinacol-pincolone. In this mechanism, the protonation of an OH group, the loss of H_2O to form a carbonium ion, then to farm more stable cation and finally loss of H^+ to form product.

SN^1 Mechanism - Some nucleophilic substitution reaction proceed with retention of configuration, even where there is no possibility of a neighbouring group effect. In SN^1 part of leaving group must be able to attack the substrate detaching itself from the rest of the group in process e.g. ROH + $COCl_2$ → ROCOCl. The SN^1 mechanism is relatively rare. The ROCOCl → RCl + CO_2.

Allylic carbon in nucleophilic substitution the substrate undergo nucleophilic substitution reaction, called allylic rearrangements when allylic substrate is treated with nucleophilies under SN^1 condition, two products formed because of allylic type of carbocation in resonance hybrid. Nucleophilie substitution at an allylic _C' can also take place by an SN^2 mechanism in which no allylic rearrangement usually takes place.

## 3.2.3 Aliphatic Electophilic Substitution

In Electrophilic Subsititution, most of leaving groups in electrophilic substitution are those that can best exist with an outer shell that is deficient in a pair of electrons. In Aromatic Systems, the most common leaving group is the proton, also in Aliphatic depending on acidity organo-Metallic compounds are susceptible to electrophilic substitution and also anionic cleavage, involving breaking of C – C bonds. So far, Aliphatic electrophilic substitution can in four major mechanisms e.g. SE_1, SE_2, (front) SE_2 (Back) and SE_1. The SE_1 is unimolecular and others are bimolecular mechanism for Aliphatic electrophilic substitution are analogous to SN_2 mechanism in that the new bond forms, as the old one breaks. In the SN_2 the incoming group brings with it a pair of electrons and this orbital can over-lap with the central carbon only to the extent that the leaving group takes away it electrons, otherwise _C' would have more than eight electrons at one in its outer shell, since electron cloud repel this means also the incoming group attacks backside from the leaving group resulting in inversion of configuration. In SN_2 (back) can be identified.

SE₂ (front)   SE₂ (back)
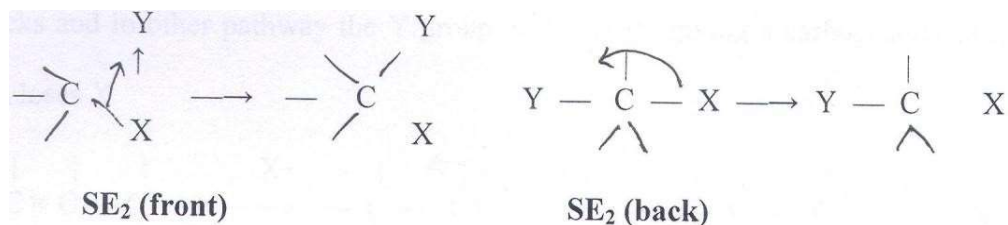
In certain cases (inversion found) but it is plain that stereochemical investigation can not distinguish between SN_2 (front) and SE_1 and stable substrate can not be prepared.

In SE_1 mechanism is analogous to the SN_1. It involves two steps – a slow ionization and a fast combination. The base catalysed tantomerization in SE_1 was obtained.
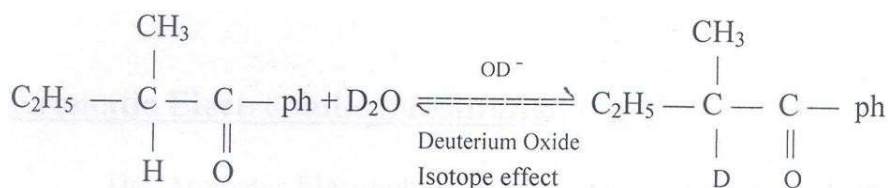

Optically active   **Racemic**

Thus inversion occurs without exchange and known as isoinversion.

The Electrophilic Substitution (ES) is accompanied by double bond shift.

When ES is carried out at an allylic substrate, the product may be rearranged. This process is analogous to the nucleophilic allylic rearrangements. There are two pathways, first is analogous to SE_1 mechanism in that the leaving group is first removed, giving a resonance-stabilized allylic carbonion and then the electrophilie attacks and in other pathway the Y group first attacks, giving a carbocataion, which then loses X


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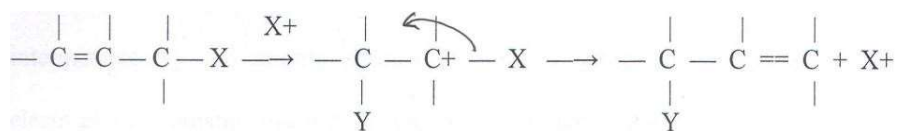
In electrophilic allylic rearrangements involve H_2 as the leaving group but Metallic leaving groups are also observed other mechanism in this are addition, elimination and cyclic mechanism are also seen.

In the case of reactivity aliphatic nucleophilic substitution and aromatic electrophilic substitution are not reliable. The effect of substrate is effect of leaving group and effect of solvent in SE_1 and SE_2 are rate determining steps.

3.2.4 Aromatic Electrophilic Substitution (AES)

The Aromatic Electrophilic Substitution reaction of aromatic Hydrocarbhon proceed by common mechanism e.g. Nitration, Halogenation etc. It takes place in two steps (I) electrophilic reagent attacks on the π electrons of the aromatic ring to form an intermediate, known as arenium cation, the sigma complex. The electromeric effect in
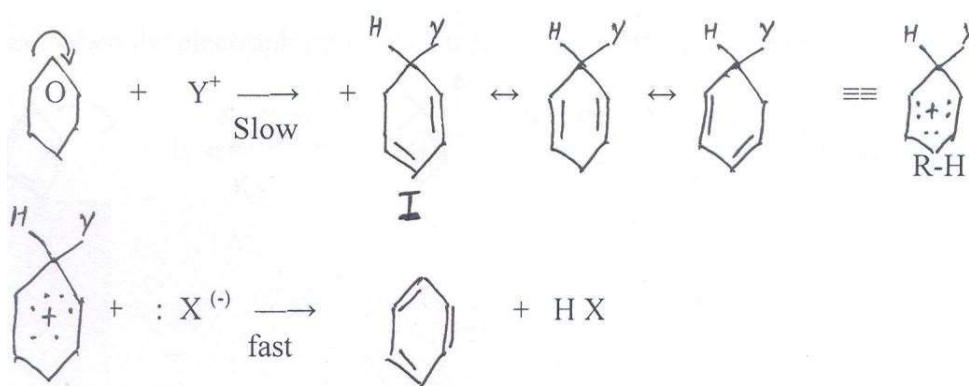

 Benzene ring and the intermediate is stabilized by resonance hybrid structure-I. The second step of the reaction involves the elimination of a proton from the intermediate by an anionic species to form a substituted compound. Thus electrophilic aromatic

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substitution reactions are bi-molecular. The arenium ions are of two kinds; one is isotope effect and second is isolation of arenium ion intermediate. If the arrival and departure of H_2' ion are simultaneous, there is isotopic effect. Arcenium ion intermediate are isolated in various ways have graphic evidence for the charge distribution.

The group already present in Benzene ring directs the incoming group either, ortho para or Meta positions. The ortho & para are activating groups but meta hinder the electrophilic substitution. The Ortho – Para directing groups are NH_2, OH, CH_3, OR, OCR and halogens. In Meta directing groups are NO_2, SO_3H, CHO. COOH etc.

In energy profile, the electrophilic substitution reaction is of second order being dependent on the concentration of each reactant as the electrophilic (E^+) approaches the Benzene ring, it forms partial bonding. This intermediate δ couplex is formed, when the electrophilic forms a true δ bond with the C' atom of the ring.
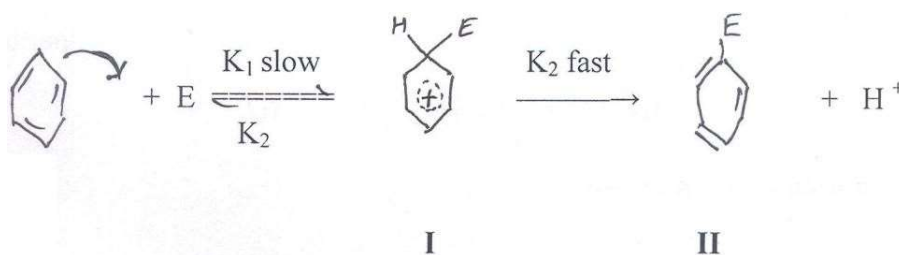
In IPSO attack at the position bearing substitution (called IPSO position) can also be important for NO_2 and possibly five reactions are seen.
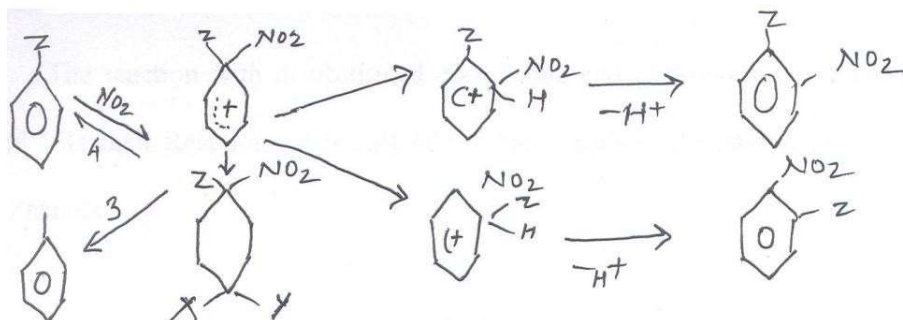
I arenium ion can lose NO$_2$ and react to starting compound **II**. The arenium ion can lose Z$^+$, aromatic substitution leaving group other than H. The **III** electrophilic group can undergo (NO$_2$), a 1, 2 migration followed by lose of proton in effect IPSO substitutent can undergo 1, 2 migration gives ortho product and V is 1,4 addition to the aromatic ring, further reactions are possible.


3.3   DIAZONIUM COUPLING

Aromatic Diazonium ions normally couple with active substrates such as Amino acids and phenols. Many products are used a dyes. The pH of solution is important.

$$ArH + ArN_2^+ - Ar – N == N – Arl$$

Arylazo-de-hydrogenation

Arenediazonium salts react readily with active substrates such as amines and phenols in weakly acidic or alkaline solutions respectively forming brightly coloured compounds called azo dyes or ice colours. This reaction is often referred to as diazo coupling.

p-Hydroxyazobenzene
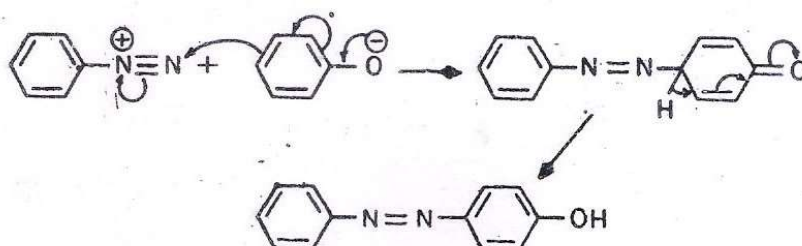(orange)

p-(N, N-Dimethylamino) azobenzene
(Yellow)
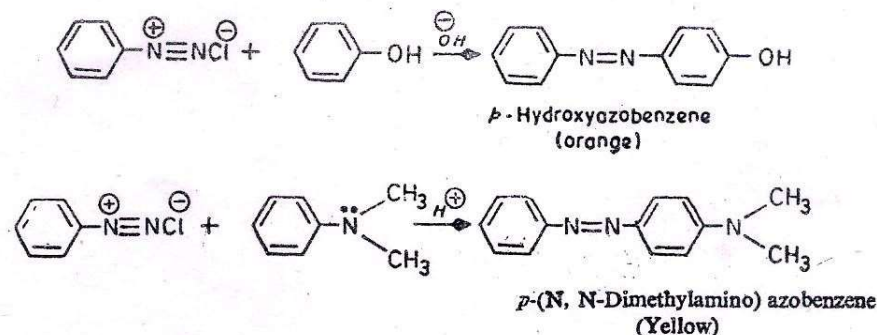
This reaction is an example of electrophilic aromatic substitution, the diazonium cation acting as an electrophile which is comparable to nitrosonium ion in its reactivity.

The other examples are :
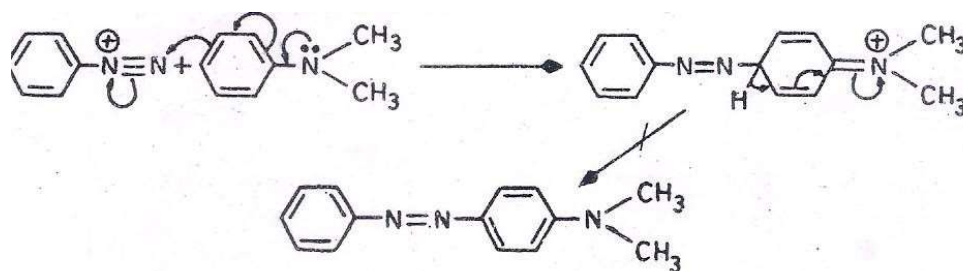
Similarly

The pH of the solution plays an important role in ease of the coupling reaction for both phenols and amines. Phenols must be coupled in slightly alkaline conditions. This is necessary as the presence of alkali converts phenols into more reactive phenoxide ions (the free phenols are not reactive enough for this reaction). If the coupling is to be carried out

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with an amine, the solution is made slightly acidic. The formation of 0- and p-azo compounds indicates that in mild acidic conditions, amines react in their unionized form. If the concentration of the acid is increased, the reaction does not occur as the free amine is converted into salt resulting in the deactivation of the ring. This is the reason why diazotization is carried out under strongly acidic solutions.

3.4 VILSEMEIR REACTION

The reaction with disubstituted dormamide and phosphorous oxychloride is called Vilsemeir Reaction. It is only applicable to active substrates such as Amines and Phenols.

$$ArH + ph-\underset{\underset{Me}{|}}{N}-\underset{\underset{O}{||}}{C}-H \xrightarrow{PoCl_3} ArCHO + phNHMe$$

Benzaldehyde
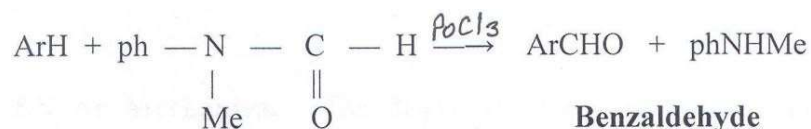
Formylation of olefins can be accomplished with N-disubstitutied formamides and $POCl_3$. This is an aliphatic Vilsmeier reaction. Vilsmeier formylation may also be performed on the α position of acetals and ketals, so that hydrolysis of the products gives keto aldehydes or dialdehydes.
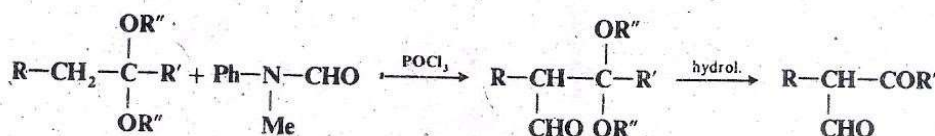
Acetylation of acetals or ketals can be accomplished with acetic anhydride and BF_3-etherate.

Addition of acyl halide to conjugated dienes usually fails since polymerization predominates. The reaction can be performed on triple-bond compounds, producing compounds of the form RCO-C=C-Cl. A formyl group and a halogen can be added to triple bonds by treatment with N, N-disubstituted formamides and $POCl_3$ (Vilsmeier raction).

3.4.1 Gatterman Coach Reaction

Formylation with $Zn (Cn)_2$ and Cl is the Gatterman Reaction.

$$ArH + Zn (Cn)_2 \xrightarrow{\text{Hcl}} ArCH == NH_2^+ Cl \xrightarrow{H_2O} ArCHO$$
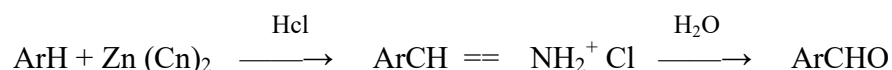
It can be applied to alkyl benzene phenols and their ethers and many heterocyclic compounds. The initial N_2 containing product is Hydrolysis to aldehydes.


3.5   AROMATIC NUCLEOPHILIC SUBSTITUTION

If a nucleophilic reagent attacks the Aromatic ring with the expulsion of a group from the site of attack, the group leaves its pair of electrons. H_2 is rarely displaced. Halogen are departing group. Since electron rich reagent attacks the ring will facilitate the reaction. The NO_2 groups are activating group. It has four mechanisms.

ph cation   Phenol
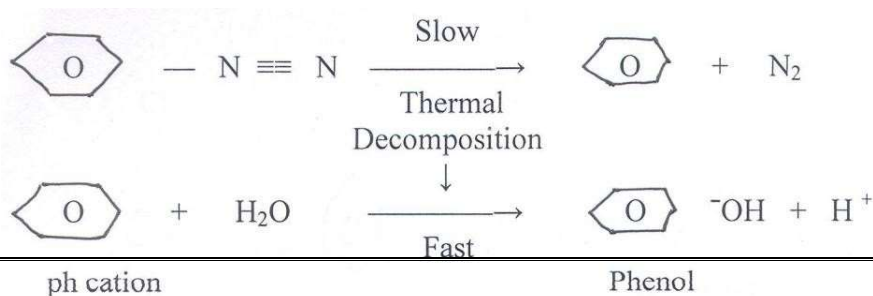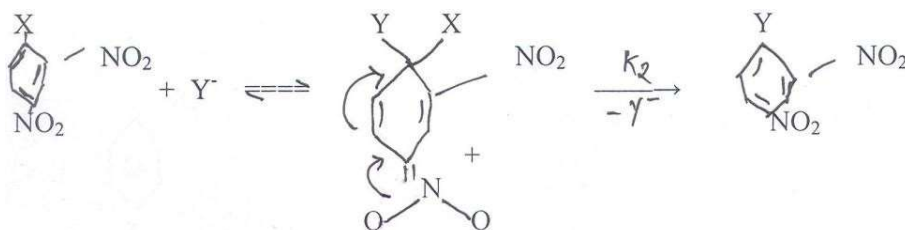
3.5.1 SN Aromatic Substitution

The displacement of group Nucleophile Y from a activated compounds e.g. 2, 4 dinitrohalobenzene involves bimolecular process.
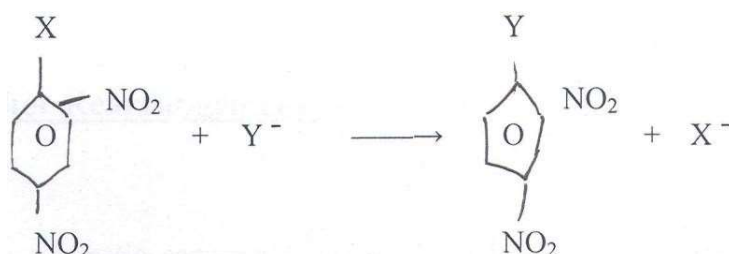
This mechanism consists of two steps, first forms complex (intermediate), the second step leaving group departs. The intermediate is called a s meisen-heimer complex. The complex intermediate has been obtained from base catalysm with primary and secondary Amines. The elimination – addition mechanism of Aromatic

Nucleophilic substitution e.g. Arylhalide when treated with strong base (Sodamide) undergo elimination – addition reaction.
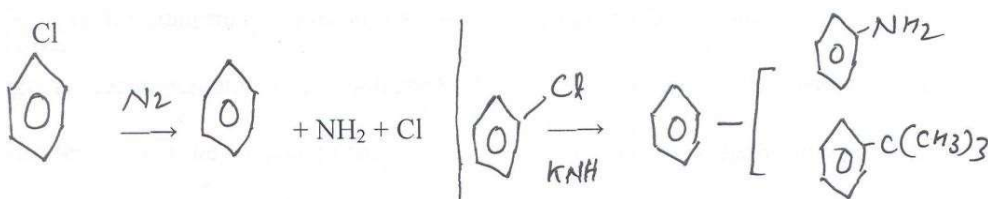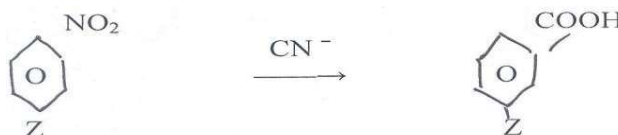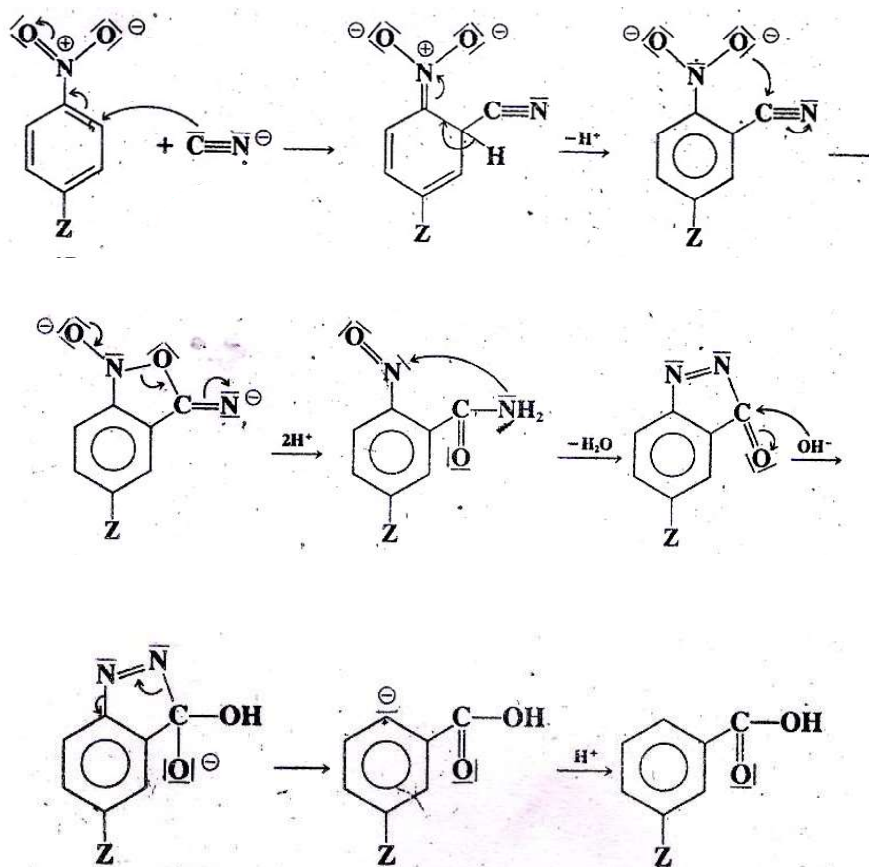
3.6 VON – RICHER REARRANGEMENTS

When Aromatic compounds are treated with cynide ion, the nitro group is displaced and carbonyl group enters in ortho to the displaced group, never Meta or Para. The scope of this reaction called **Von-Richer Rearrangement**. The reaction gives good

results when electrons withdrawing groups are in ortho or para positions, but yield is poor.

Bunnett and Rauhut demonstrated that α-naphthyl cynide is not hydrolyzable to α-naphthoic acid under conditions at which β-nitronaphthalene undergoes the von Richter rearrangement to give α-naphthoic acid. This proved that the nitrile cannot be an intermediate in this case and cast doubt on all other cases, since it is unlikely that different mechanisms would be operating. It was subsequently demonstrated that elemental nitrogen is a major product of the reaction. It had previously been assumed that all the nitrogen in the reaction was converted to ammonia, which would be compatible with a nitrile intermediate, since ammonia is a hydrolysis product of nitriles. At the same time it was shown that NO_2^- is not a major product. The discovery of nitrogen indicated that a nitrogen-nitrogen bond must be formed

during the course of the reaction. A mechanism in accord with all the facts was proposed by Resenblum :

The rearrangement occurs with high yields and can be performed with various groups of present in the ring. The reaction is most often carried out with three methyl groups on the nitrogen, but other groups can also be used, though if a β-hydrogen is present, Hofmann elimination (7-6) can and often does compete. When the three groups are not the same, competing products may be obtained, e.g.,

3.6.1 Sommelet Hauser Rearrangement

Benzylic quaternary Ammonium salt when treated with alkali-metal Amides, undergo a rearrangement called Sommelet Rearrangement since the product is a benzylic tertiary amine, it can further alkylated and the product again subjected to rearrangement. The benzylic Hydrogen is acidic and looses a proton and gives rearrangements.
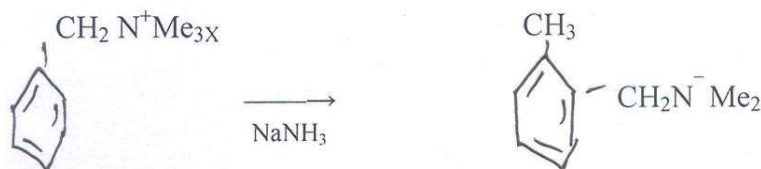
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carried out with three methyl groups on the nitrogen, but other groups can also be used, though if a β-hydrogen is present, Hofmann elimination (7-6) can and often does compete. When the three groups are not the same, competing products may be obtained, e.g.,
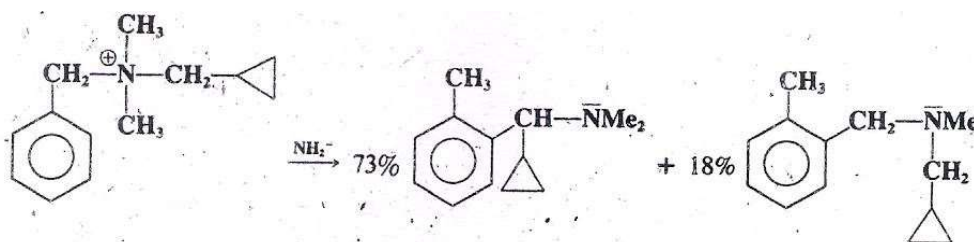
In the case, the Stevens rearrangement is a competing process. When both rearrangements are possible, the Stevens if favored at high temperatures and the Sommelet0Hauser at low temperatures. When the migrating group carries an α-SR group, the Sommelet-Hauser product is an aromatic aldehyde, formed by hydrolysis during the workup of the ArCH(SR')NR$_2$ product. The mechanism is -
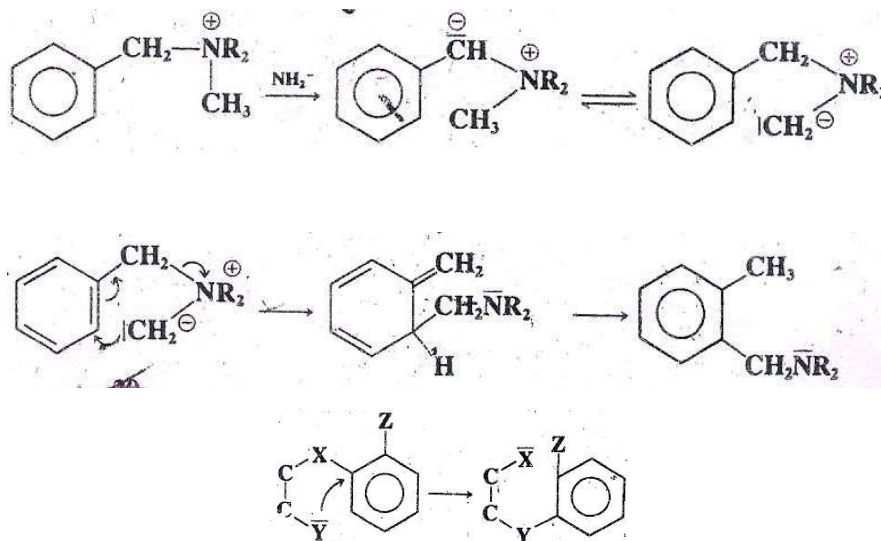
A specific example is :
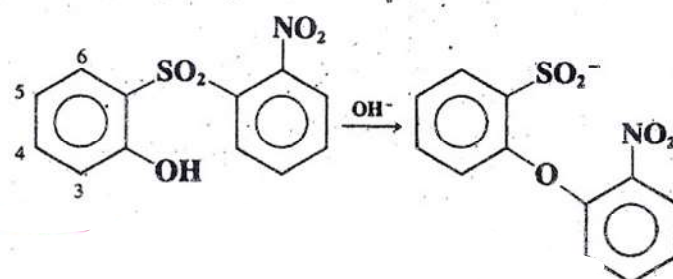
3.6.2 Smiles Rearrangement

It comprises a group of rearrangements that follows the pattern given below:-
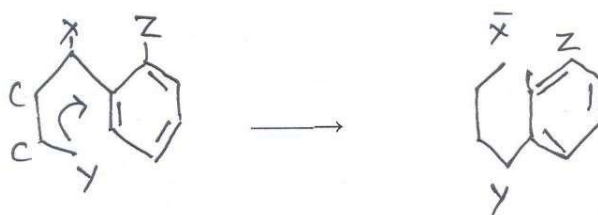
The SO_2 Ar is the leaving group and nucleophilic and the NO_2 group serves to activate the ortho position.
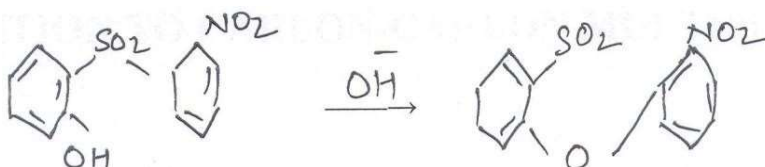
Smiles rearrangements are simply intromolcular nucleophilic substitutions. In the example given, SO_2 Ar is the leaving group and ArO⁻ the nucleophile, and the nitrogroup serves to activate its ortho position.

The ring at which the substitution takes place is nearly always activated, usually by ortho or para nitro groups. X is usually S, SO, SO_2 O, or COO. Y is usually the conjugate base of OH, NH_2, NHR, or SH. The reaction has even been carried out with Y = CH_2^- (phenyl-lithuim was the base here).

The reaction rate is greatly enhanced by substitution in the 6 position of the attacking ring, for steric reasons. For example, a methyl, chloro, or bromo group in the 6 position caused the rate to be about 10^5 times faster than when the same groups were in the 4 position, though electrical effects should be similar at these positions. The enhanced rate comes about because the most favourable conformation the molecule can adopt to suit the bulk of the 6-substituent is also the conformation required for the rearrangement. Thus, less entropy of activation is required.

LET US SUM UP

The Electrophilic and Neucleophilic Fissions, Homo & Hetro, Carbocation Rearrangement, SN^1 Mechanism, Aliphatic & Aromatic,

Electrophilic & Neucleophilic Substitutions, Diazonium Coupling &

name reaction, pertaining the same, has been explained.

CHECK YOUR PROGRESS – One – THE KEY

a) 3.2.1 – Neighbouring Group Mechanism
b) 3.5   - Aromatic Neucleophilic Substitution
c) 3.5.1 - SN Aromatic Substitution

CHECK YOUR PROGRESS –Two – THE KEY

a) 3.3   - Diazonium Coupling
b) 3.2.4 - Aromatic
c) 3.4   - Vilesmeir
d) 3.6   - Von-Richer

***

UNIT – IV : ADDITION TO CARBON - CARBON MULTIPL BONDS

Structure

4.0   INTRODUCTION

In this unit, it has been highlighted that how the Carbon-Carbon multiple bonds reacts and forms various molecules, whether the molecules are Homo or Hetero. How the condensation of multiple bonds of the molecule takes place, giving rise various molecules synthetically? How the addition may be Electrophilic or Neucleophilic takes place in the molecules. Hydrogenation and Epoxidation are explained.

4.1   OBJECTIVE

The Carbon Chemistry deals with bonding, whether it is the addition of substitution or C-C bonding or with multiple bonding. The importance of free radical and its reactivity is explained in this Chapter.

4.2   ADDITION REACTION IN DOUBLE

Addition reaction in double and triple bond takes place due to Electrophiles, Nucleophilies and Free Radical Mechanism. In Electrophilic addition reaction, a positive species approaches the double bond in first step, forms a bond by converting the π pair of electrons into a δ pair.   The first step carbonium ion is formed and second step combine with a species carrying a electron pair, which is the second pair of SN_1 mechanism. The intermediate is similar to the neighbouring group mechanism of Nucleophilic substitution.
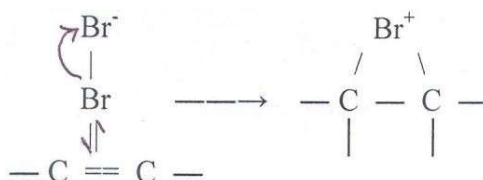
–Bromonium-ion‖ is an SN_2 mechanism of nucleophilic substitution on this intermediate and called Ad E_2 (Electrophilic addition bi-molecular). The two carbons of the double bond and the four atoms soon attached to them are still in a plane, there are thus three possibility Y & W may enter from the same side of the plane. In which case the addition is stereospecific and syn, they may enter from opposite sides for stereospecific anti-addition or the reaction may be non-stereospecific. To determine

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the possibility YW is added to the CIS and Trans isomers of an olefin of the form ABC == CBA, if the addition is syn, the product will be the erythero dl pair, because each _C' has a 50% chance of being attacked by Y.

4.2.1

<u>Syn addition</u>
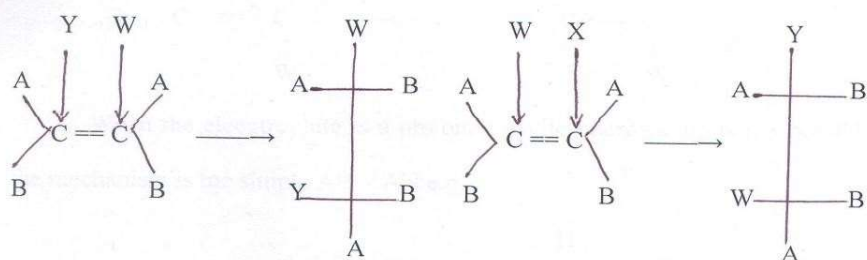
4.2.2

<u>Anti-addition</u>
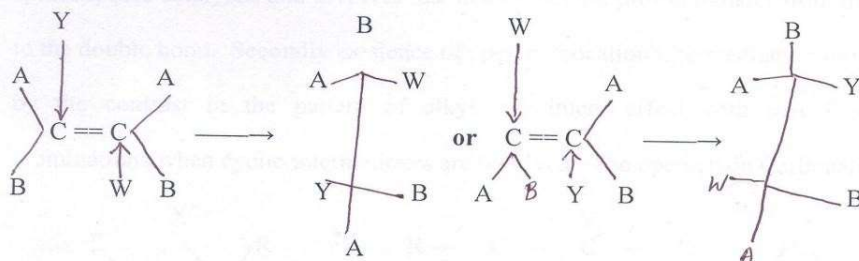
If addition is anti, the three dl pair will be formed and the trans isomer will give the opposite results. The threo pair, if the addition is Syn & erythro pair and if it is Anti. In addition to triple bond compounds of the type uc ==CA, syn addition results in a Cis Olefin and Anti-addition in a trans olefin. If W & Y attack on the side of the plane as Y collapse of the ion pair leads to syn addition. If the attack of W & Y are simultaneous but from opposite side called the AdE$_2$ (Termolecular addition).

Y   Y

$$> \overset{\uparrow}{\underset{\underset{W}{\uparrow}}{C}} == C < \longrightarrow \quad - \overset{|}{\underset{|}{C}} - \overset{|}{\underset{W}{C}} -$$
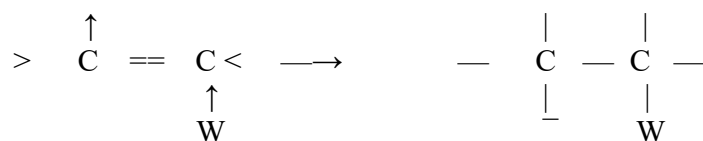
When the elecgtrophite is a proton, a cyclic intermediate is not possible and the mechanism is the simple AH + AN e.g.

$$- \overset{|}{C} == \overset{|}{C} - \ + \ H^+ \ \xrightarrow{\text{Slow}} \ - \overset{|}{C^+} - \overset{\overset{H}{|}}{\underset{|}{C}} - \ \xrightarrow{W^-} \ - \overset{\overset{W}{|}}{\underset{|}{C}} - \overset{\overset{H}{|}}{\underset{|}{C}} -$$
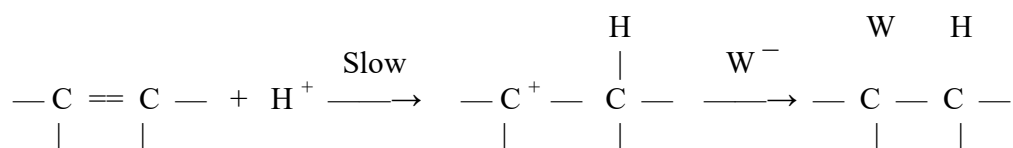
It is a A-SE$_2$ mechanism, with the following evidences. If the reaction is not specific, acid catalysed and involves rate determination, proton transfer from the acid to the double bond.   Secondly existence of open carbocation intermediate is supported by the contrast in the pattern of alkyl substituent effect with that found in brominations when cyclic intermediates are involved. The open chain Carbonation is prone to

$$\begin{array}{cc}
\overset{X^+}{R\diagup\!\!\diagdown R} & R - \overset{+}{\underset{\underset{R}{|}}{C}} - \overset{Y}{\underset{\underset{R}{|}}{C}} - R \\
R\diagup\!\!\diagdown R &
\end{array}$$
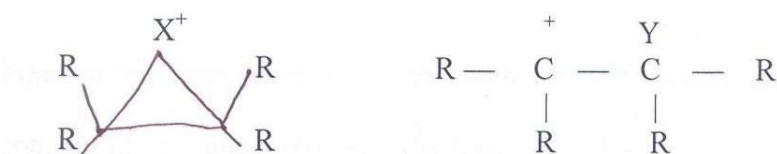
rearrangement and addition of HX to triple bond has the same mechanism, though the intermediate in this case is a vinyl cation.

$$- C \equiv \overset{+}{C} - \xrightarrow{H^+} - C \equiv \overset{\overset{H}{|}}{\overset{+}{C}} -$$
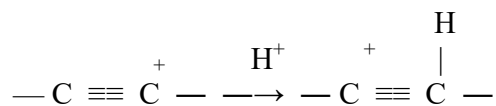
4.2.3 Nucleophilic Addition

This mechanism is the same as the simple electrophile but charges are reversed. In this, the first step carbonion formed y the nucleophile and in second step carbonion reacts with positive species.

$$-\overset{|}{\underset{|}{C}}==\overset{|}{\underset{|}{C}}- + Y^- \longrightarrow -\overset{|}{\underset{|}{C}}-\overset{\overset{Y}{|}}{\underset{|}{C}}- + W^+ \longrightarrow -\overset{\overset{W}{|}}{\underset{|}{C}}-\overset{\overset{Y}{|}}{\underset{|}{C}}-$$
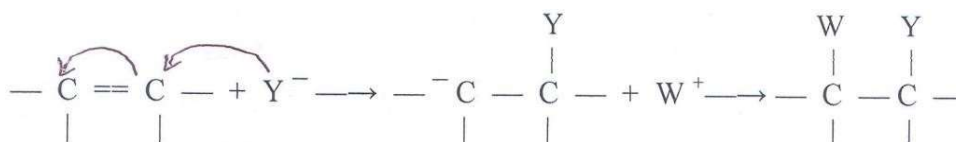
Addition of HY to a substrate of the form $- C == C - Z$ where Z = CHO, COR, $CONH_2$, CN, NO_2, SOR. SOR addition always follows a nucleophilic mechanism with _Y' bonding with the _C' away from Z group.

$$\overset{O}{\underset{\overset{Y}{|}}{\underset{|}{—C}}} == \overset{|}{\underset{|}{C}} — \overset{|}{\underset{|}{C}} == \underline{O}1 \longrightarrow \left[—\overset{|}{\underset{|}{C}} — \overset{\overset{Y}{|}}{\underset{|}{C}} == \overset{O}{\underset{|}{C}} — \underline{O}1 \longleftrightarrow — \overset{|}{\underset{|}{C}} — \overset{\overset{Y}{|}}{\underset{|O}{C}} == \underline{O}1 \right] \rightarrow HY$$

$$— \overset{\overset{Y}{|}}{\underset{|}{C}} — \overset{|}{\underset{|}{C}} == \overset{|}{\underset{|}{C}} — OH ==== — \overset{\overset{Y}{|}}{\underset{|}{C}} — \overset{\overset{H}{|}}{\underset{\underset{C}{|}}{C}} — \overset{|}{\underset{|}{C}} == O ,$$
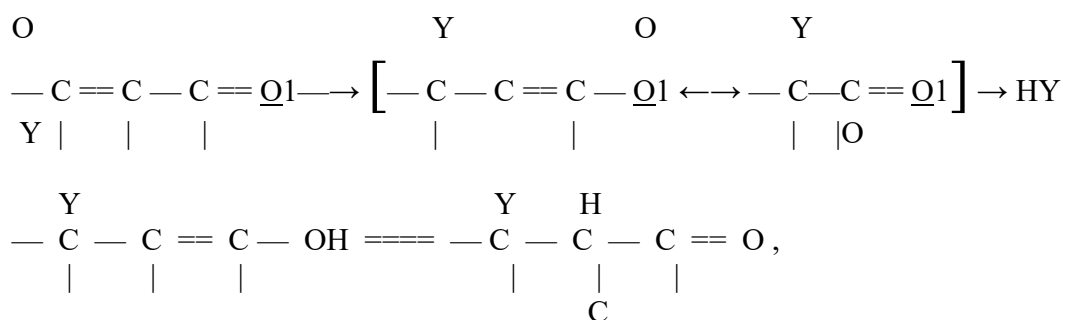
protonation of the enolate ion is chiefly at the oxygen which is more negative than the carbon, but this produces the enol which tantomerizes.

When Z is CN or a C == O group, it is also possible for Y to attack at this _C' and reaction competes, when it happens, it is called I Z addition, 1, 4 addition to these substrates is also known as conjugated addition. Y⁻ never attack at the 3 position, since the resulting carbon ion would have no resonance stabilization e.g. acrylonitrile and 1, 4 addition to it is called cynoethylation because the Y is cyanoethylat with

$$— \overset{\overset{Y}{|}}{\underset{|}{C}} — C == C — OH === — \overset{\overset{Y}{|}}{\underset{|}{C}} — \overset{\overset{H}{|}}{\underset{|}{C}} — C == O$$

|　　　|　　　|　　　　　　　　　　|　　　|

Enol　　　　　　　　　　　　　　　　　**Keton**

$$H_2C == CH - CN + HY \longrightarrow YCH - CH_2 - CN$$
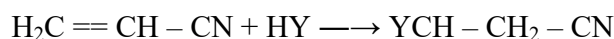
any substrate the Y is an ion of the type $Z - CR -_z$, the reaction called Michael reaction.

$$H_2C == CH - CN + HY \longrightarrow Y - CH_2 - CH_2 - CN$$
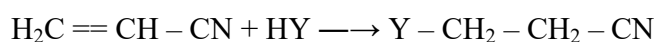
The effect of substitutes is so great that it is possible to make the statement that simple olefins do not react by the nucleophilic mechanis, and polyhalo or polycyano olefins do not generally react by the electrophilic mechanis. There are some reagents that attack only as nucleophiles, e.g., ammonia, and these add only to substrates susceptible to nucleophilc attack.

4.2.4 Free Radical Addition

When a radical is generated, the reaction proceeds with intermediate –

$$\begin{array}{ccc} & & Y & & W \quad Y \\ & & | & & | \quad | \\ -C == C- + Y_1 \longrightarrow & -C-C- + YW \longrightarrow & -C-C- + Y\cdot \\ & & | \quad | & & | \quad | \end{array}$$

$$YW \xrightarrow[\text{Dissociation}]{\text{hv or spontaneous}} Y\cdot + W- \textbf{ or } R\cdot + YW \longrightarrow RW + Y\cdot$$
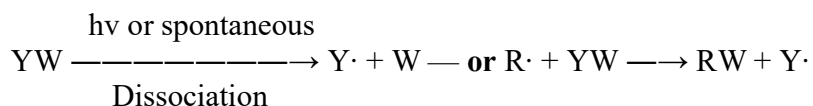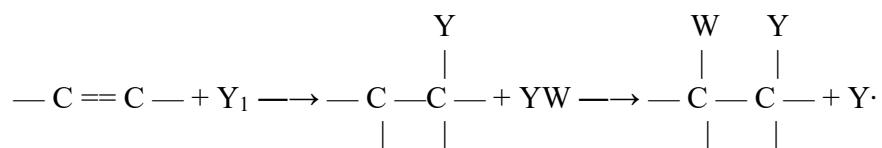
The II is an abstraction, so W is always univalent, it may be hydrogen or halogen.

Termination of the chair can occur in any way- if (A) adds to another olefin molecule

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a dimmer is formed which can add to still another and chain long or short may be built up. When free radicals are added to 1, 5 and 1, 6 denies, the initially formed radical can add inter-a-molecularly to the other bond, leading to acyclic product.

$$| \quad | \quad + Y° \rightarrow | \quad | \rightarrow | \quad | + YW \rightarrow | \quad | + Y°$$
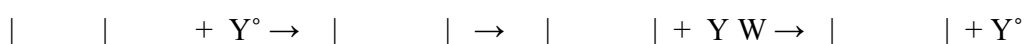
When attack is not at the centre of double bond but both carbon atom attacked simultaneously called **Diel & Alder Reaction** in cyclo mechanism when eletrophilic addition.

$$\begin{array}{ccc} Y & W & \quad Y \quad W \\ \downarrow\nearrow & & | \quad\quad | \\ -C == C & \longrightarrow & -C- \ C- \\ | \quad | & & | \quad\quad | \end{array}$$
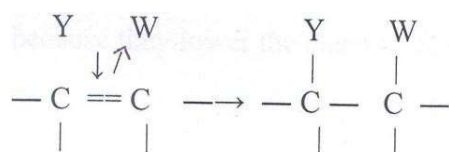
on a 2 double bond containing compound in conjugatin 1, 2 addition products are obtained (B), there is also a 1, 4 addition product (C) obtained.

$$\begin{array}{c} C \quad\quad\quad Y \ \ W \quad\quad\quad\quad Y \quad\quad\quad\quad W \\ || \quad\quad\quad | \ \ | \quad\quad\quad\quad | \quad\quad\quad\quad | \\ -C == C - C + YW \rightarrow -C - C - C == C - \rightarrow -C - C - == C - C- \\ | \quad | \quad | \quad\quad\quad | \quad | \quad | \quad | \quad\quad\quad | \quad | \quad | \quad | \end{array}$$

$$\text{(B)} \quad\quad\quad\quad\quad \text{(C)}$$
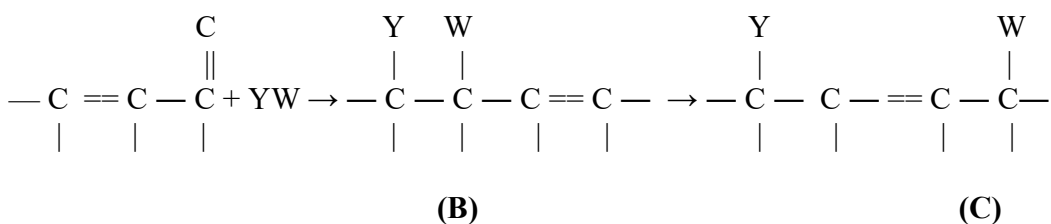
Bromination with olefin can form cyclic structures.

4.3 ORIENTATION & REACTIVITY

In this, the electrophilic aromatic substitution electron donating groups increase the reactivity of a double bond toward electrophilic addition and electron withdrawing groups decreases it. The electrophilic addition of a group increases in olefins –

$CCl_3CH == CH_2 < Cl_2CHCH == CH_2 < ClCH_2 – CH == CH_2 < CH_3CH_2 == CH_2$

for nucleophilic addition the situation is reversed. The Nucleophilic e.g. NH_3 and electrophilic e.g. Cl_2 and F_2 have decreasing ability as given below:-

$Z == NO_2$, COAr, CHO, COR, SO_2Ar_1, CN, COOR, SOAr, $CONH_2$

Electron withdrawing groups enhances nuclophilic addition and inhibit electrophilic addition because they lower the electron density of the double bond.

It seems obvious that electron-withdrawing groups enhance nucleophilc substitution and inhibit electrophilic substitution because they lower the electron density of the double bond. This is probably true, and yet similar reasoning does not always apply to a comparison between double and triple bonds. There is a higher concentration of electrons between the carbons of a triple bond than in a double bond, and yet triple bonds are less subject to electrophilic attack and more subject to nucleophilic attack than double bonds.

Still, it is true that in general triple bonds are more susceptible to nucleophilic and less to electrophilic attack than double bonds, in spite of their higher electron density. One explanation for this is that the electrons in the triple bond are held more tightly because of the smaller carbon-

carbon distance; it is thus harder for an attacking electrophile to pull out a pair.

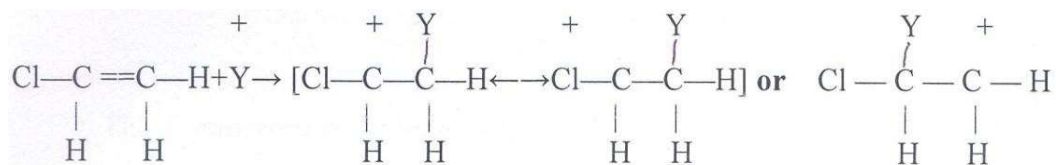In **Markonikov's**, the positive portion of the reagent goes to the side of the double or triple bond having more H_2, but Br_2 adds to double bond e.g. Y^+ adds to that side, where more stable carbocation. The alkyl group, secondary carbocation are more stable than primary.

$$R - C = C - H + Y^+ \longrightarrow R - \overset{+}{C} - C - H \text{ or } R - \overset{Y}{\underset{|}{C}} - C - H$$

More stable

$$Cl - C = C - H + Y \rightarrow [Cl - C - C - H \leftrightarrow Cl - C - C - H] \text{ or } Cl - \overset{Y}{\underset{|}{C}} - C - H$$
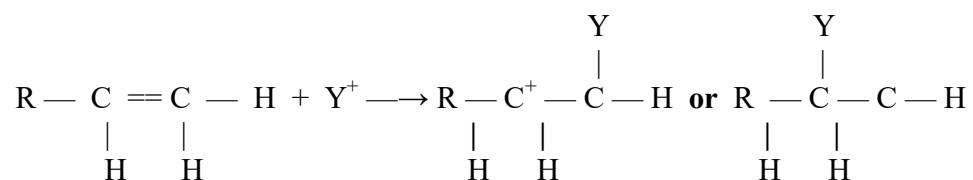
More stable

According to the **"Hammond pastulate"**, the lower energy transition state and **Markonikov's** rule also applies for halogen substituents because halogen stabilizes the carbocation by resonance.

For nucleophilic addition the direction of attack has been studied very little, except for Michael-type addition, with compounds of the type $C = C - Z$. Here the negative part of the reagent always attacks regioselectrively at the carbon that does not carry the Z.

In free radical addition the main effect seems to be steric. All substrates $CH_2 = CHX$ are preferentially attacked at the CH_2, regardless of the identity of X or of the attacking radical. With a reagent such as HBr, this means that the addition is anti-Markovnikov :

preferentially
formed
intermediate   product
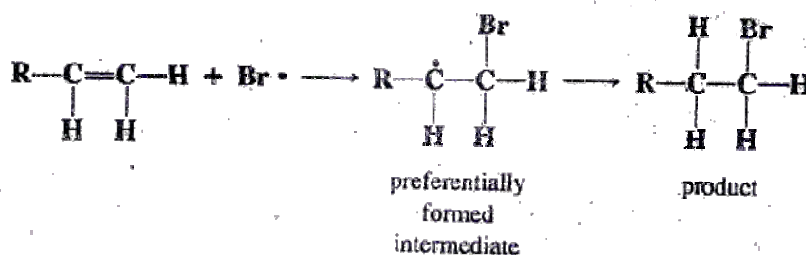
Thus the observed orientation in both kinds of HBr addition (Markovnikov electronphilic and anti-Markovnikou free radical) is caused by formation of the secondary intermediate. In the electrophilic case it forms because it is more stable than the primary; in the free-radical case because it is sterically preferred. The stability order of the free-radical intermediates is also usually in the same direction : $3^o > 2^o > 1^o$, but this factor is apparently less important than the steric factor. Internal olefins with no groups present to stabilize the radical usually give approximately a 1:1 mixture.

The **Regio-Selectivity** reveals a reaction to give two or more structural isomers but actually produces only one, the reaction' is called **Regio-selectivity** e.g. Nucleophilic NCO usually given only isocyanate RNCO and not isomeric cynates ROCN or RNCO.

In **Chemo-selectivity** – a reducing agent usually depends on what other functional groups are present; each reducing agent reduces certain groups and not others, known

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as **Chemo-selectivity**. Ketons can be chemo-selectively reduced in the presence of oldehydes with NaBH in aquous EtOH in presence of ceriumtrichloride at 15º C.

4.3.1 Addition to Cyclopropane Ring

The Cyclopropane undergo addition reaction like double bond containing compounds resulting in the opening of the three membered rings, having electrophilic attack and also –

$$\Delta \; + \; HBr \longrightarrow CH_3CH_2Br$$
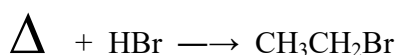
follows **Markonikove's rule** eg. 1, 2 trimethylcyclo-propane with HX
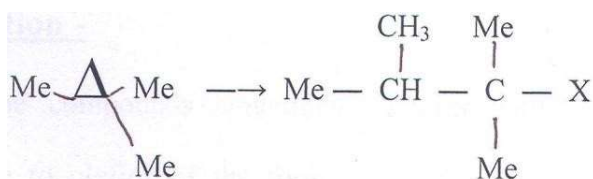
Additions to cyclopropanes can take place by any of the four mechanism discussed, but the most important type involves electrophilic attack. For substituted cyclopropanes, these reactions usually follow Markovnikov's rule, though exceptions are know and the degree of regioselectivity is often small. The application of Markovnikov's rule to these substrates can be illustrated by the reaction of 1, 1, 2-trimethylcyclopropane with HX. The rule predicts that the electrophile (in the case H^+), goes to the carbon with the most hydrogens and the nucleophile goes to the carbon that can be stabilize a positive charge.
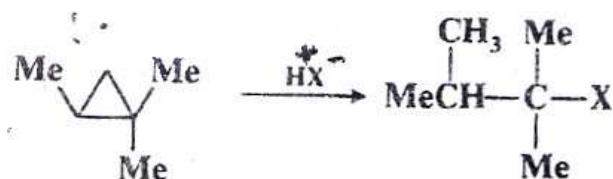
Free-radical additions to cyclopropanes have been studied much less, but it is known that Br_2 and Cl_2 add to cyclopropanes by a free-radical mechanism in the presence of uv light. The addition follows Markovnikov's rule, with the initial radical attacking the least-substituted carbon and the second group going to the most-substituted position.

4.4   HYDROGENATION OF DOUBLE & TRIPLE BONDS

Most of the $\_C'\_C'$ double bonds whether substituted by electron donating or withdrawing substituents can be catalytically hydrogenated usually in quantitative yields. Two types of catalyst used – **(1) Heterogenous catalyst and (2) Homogenous**. All alkenes added hydrogen at $0º$ C to $275º$ C. Hydrogenation in most cases carried out at room temperature and just above atmospheric pressure but not for all double bonds. In Aromatics, the mechanism involved electrons which are transferred from the metal to the solvent and hence to the ring.

When olefins are treated with borane in ether solvent, BH_3 add across the double bond. The borane inform of complexes with THF, Me_2S & BF_3 etherate. Olefine give -
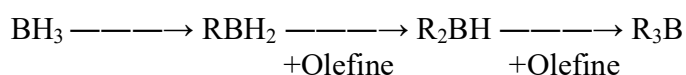
$$BH_3 \longrightarrow RBH_2 \longrightarrow R_2BH \longrightarrow R_3B$$
$$\quad\quad\quad\quad\quad +\text{Olefine} \quad\quad\quad +\text{Olefine}$$

These compounds are useful intermediates and Alkyl boranes on oxidation H_2O_2 and NaOH are converted into Alcohols.

4.5 MICHAEL REACTION

The compounds containing electron withdrawing groups add in presence of base to olefins of the form $C == C - Z$ called **Michael Reaction** involving conjugated addition. The component of this reaction is acceptor, **Addenda & Catalyst**.

$$C_6H_5\ CH == CH\ .\ COOC_2H_5 \xrightarrow[\text{C}_2\text{H}_5\text{ NO}]{+\ CH_2\ (COOC_2H_5)_2\text{Methyl propionate is addendum}} C_6H_5 — CH — CH_2\ COO\ C_2H_5$$

$$\underset{\text{CH. (COO C}_2\text{H}_5)_3}{|}$$
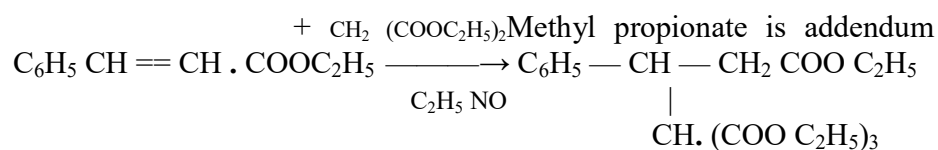
     Acceptor   **Catalyst**

This reaction is used for various product applications.

Thus,
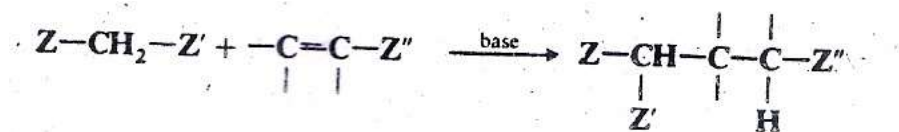
Compounds containing electron-withdrawing groups add, in the presence of bases, to olefins of the form $C = C - Z$ (including quinones). The base removes the acidic proton. The reaction has been carried out with malonates, cyanoacetates, acetoacetates, other β-keto esters, and compounds of the form $Z - CH_3, ZCH_2R, ZCHR_2$, and $ZCHRZ^1$ including esters, ketones, aldehydes, nitriles, nitro compounds, and sulfones, as

well as other compounds with relatively acidic hydrogens, such as indenes and fluorenes. These reagents do not add to ordinary double bonds, except in the presence of free-radical initiators. 1, 2 addition (to the C = O or C $\equiv$ N group) often competes and sometimes predominates. In particular, α, β-unsaturated aldehydes seldom give 1, 4 addition.

$$Ph_3P + X-\underset{R'}{CH}-R \xrightarrow{0\text{-}45} Ph_3\overset{\oplus}{P}-\underset{R'}{CH}-R \; \overset{X^-}{} \xrightarrow{BuLi} \left[Ph_3\overset{\oplus}{P}-\underset{R'}{\overset{\ominus}{C}}-R \longleftrightarrow Ph_3P=\underset{R'}{C}-R \right]$$

Phosphonium salt   Ylide
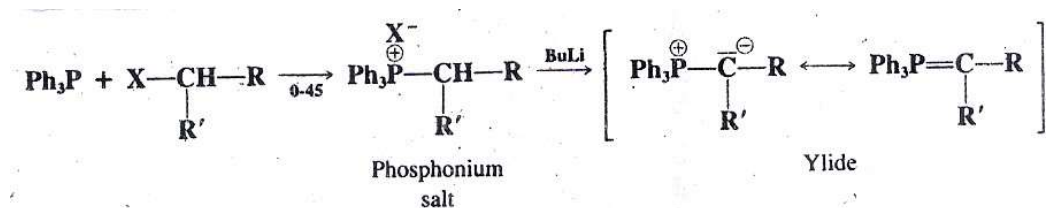
4.5.1 Orientation & Reactivity

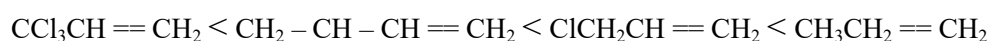The electronic or electron donating groups increase the reactivity of a double bond towards the electrophilic addition and electron withdrawal group decreases reactivity towards the electrophilic addition of a group of olefins increased in the order.

$$CCl_3CH = CH_2 < CH_2 - CH - CH = CH_2 < ClCH_2CH = CH_2 < CH_3CH_2 = CH_2$$

For nucleophilic addition the situation is reversed.

In **Electrophilic Addition**, the reaction of olefins take place in polar medium and are supposed to take stepwise as – Bromine molecule is polarized due to proximity of –

$$CH_2 = CH_2 \qquad Br - Br \xrightarrow{< C = C <} Br^{8+} B^{5-}$$

π **complex**

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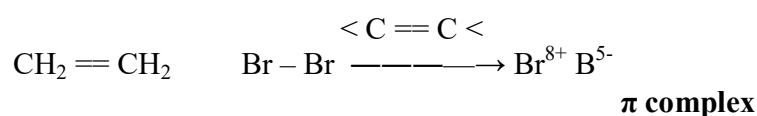
electrons of π bond of alkane. The polarized Br_2 forms less stable complex with π cloud of the alkene. Nucleophilic attack of bromide ion, alkene gives rise dibromotrans compound.

$$> C - C + Br \longrightarrow > C - C <$$

T.dibromo

4.5.2 Free Radical

When reactants are in vapour phase in sunlight and in the presence of peroxides and non-polar solvents, the reaction . The free radical reactions are inhibited by presence of oxygen.
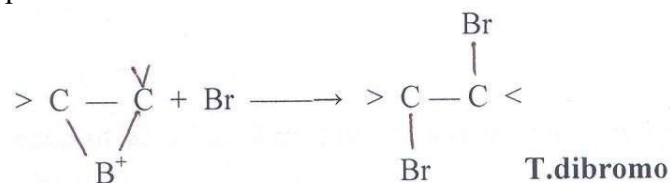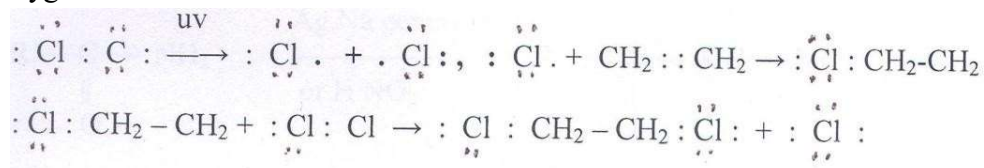

$$: \overset{..}{\underset{..}{Cl}} : \overset{..}{\underset{..}{C}} : \overset{uv}{\longrightarrow} : \overset{..}{\underset{..}{Cl}} . + . \overset{..}{\underset{..}{Cl}} :, \quad : \overset{..}{\underset{..}{Cl}} . + CH_2 :: CH_2 \rightarrow : \overset{..}{\underset{..}{Cl}} : CH_2\text{-}CH_2$$

$$: \overset{..}{\underset{..}{Cl}} : CH_2 - CH_2 + : \overset{..}{\underset{..}{Cl}} : Cl \rightarrow : \overset{..}{\underset{..}{Cl}} : CH_2 - CH_2 : \overset{..}{\underset{..}{Cl}} : + : \overset{..}{\underset{..}{Cl}} :$$

4.6 SHARPLESS ASSYMETRIC EPOXIDATION

The allylic alcohols are converted to optically active epoxides by reacting with t – BuOH, Titanium tetraisopropoxide and optically active di-ethyl tertarate. The attack on the substrate by a compound formed from titanium alkoxide and di-ethyl tartarate to produce a complex that also contains the substrate and the t-BuOH, ordinary alkens have been enontioselectivityly epoxidised with Na Hypochlorate and an optically active magnese complex as catalyst – Assymetric synthesis is the example of titanium catalys epoxidation. Athyl Alcohol (pri, di & tri) with butyl hydro-oxide with Ti is isopropoxide and optically active diethyl tartarate.

4.7 ADDITION TO CARBON – HETERO MULTIPLE BONDS

In presence of acid and base catalyst unsaturated Amides $RCONH_2$ can be hydrolyzed with formation of free acid and NH_4 ion when diajonium ion hydrolyze much faster than ordinary hydrolysis e.g. –

$$R - \underset{\underset{O}{\|}}{C} - NH_2 \quad \xrightarrow[\text{or H } NO_2]{\text{Ag.Na peroxide}} \quad R - \underset{\underset{O}{\|}}{C} - OH \; + \; N_2$$
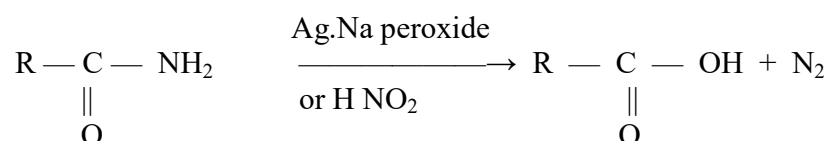
Acid-Base catalyzed hydrolysis are essentially irreversible salts are formed in both cases.

4.7.1 Addition to Grignard Reagent

The magnesium metal reacts with alkyl halides in presence of dry ether to form alkyl magnesium metal halide (R – Mg – X), which remains dissolved in ether. R may be alkyl or Aryl radical. In the Nucleophilic addition reaction of **Grignord Reagent** with compounds, is having unsaturated group or multiple bonds e.g. $> C == O, > C = S, - C == N$ **or** electronegative atoms O & S. The alkyl group attaches to the electro-

| Check your progress – 1 |
|---|
| Notes :- 1.   Write your answers in the space given below.
        2.   Compare your answers with ones given in the end of the unit. |
| a)   Addition to Carbon – Hetero Multiple bonds.
     b)   Orientation & reactivity
     c)   Neucleophilic addition
 ……………………………………………………………………………………
 ……………………………………………………………………………………
 ………………………………………………………………………………….. |

positive element _C' atom of the unsaturated group and electropositive MgX fragment attaches to more electronegative elements O, S & M etc.

$$— C = O + RMgX \longrightarrow — \overset{|}{\underset{|}{C}} — OMgX \longrightarrow — \overset{|}{\underset{|}{\underset{R}{C}}} — OH + MgXOH$$
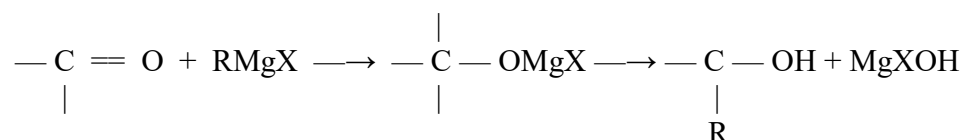
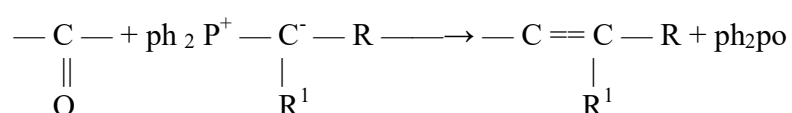The addition products can be hydrolyzed by HOH Mercaptans, pri, sec & ter. Alcohols also obtained accordingly.

The Organolithium Reagents to carbonyl and unsaturated carbonyl compounds. The organolithium compounds are less reactive but more reactive than Mg analogues and undergo addition reaction.

$$RX + 2 Li \xrightarrow[-10° C]{Dry N_2} RIi + Lix \qquad \text{Organolithium compound}$$
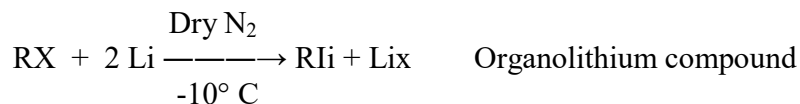
4.8 WITTING REACTION (Alkylidene – De – OXO – Bi-substitution)

The aldehydes or ketones are treated with phosphorous to yield an olefin. The phosphorous Y lides are usully proposed by treatment of a phosphorium salt with a base and phosphonium salts are casually prepared from phosphere and an alkyl halide.

$$— \overset{}{\underset{\underset{O}{||}}{C}} — + ph_2 P^+ — \overset{}{\underset{\underset{R^1}{|}}{C^-}} — R \longrightarrow — C = \overset{}{\underset{\underset{R^1}{|}}{C}} — R + ph_2po$$

It involves the preparation of olefins by interaction of Aldehydes, Ketones with Triphenyl phosphoric alkylidenes.

The phosphorus ylide may also contain double or triple bonds and certain functional groups. Simple ylides (R, R' = hydrogen or alkyl) are highly reactive, reacting with oxygen, water, hydrohalic acids, and alcohols, as well as carbonyl compounds and esters so that the reaction must be run under conditions where these materials are absent. When an electron-withdrawing grop, e.g., COR, CN, COOR, CHO, is present in the α position, the ylides are much more stable.

4.8.1 Aldol condensation

Condensation of two molecules of an aldehyde or a ketone to form β- hydroxyl aldehyde or a β- hydroxyl ketone.
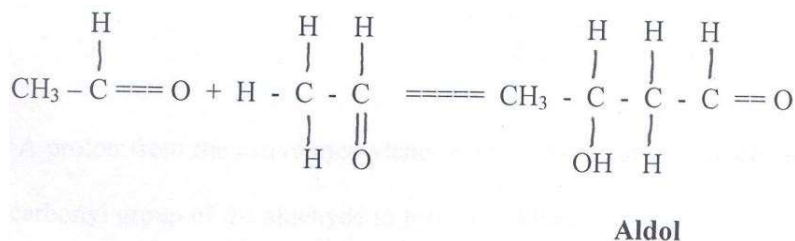
Aldol

The aldol condensation fecilitated by -1 group on the carbonyl component and retarded by +1 group as group as described in CH_3 CHO & CH_3 CO CH_3 condensation. The condensation is reversible. Aldol products can be dehydrated to δ, β unsaturated aldehydes.

OH   Mineral acid
 |

$$CH_3 - CH.CH_2 CHO \longrightarrow CH_3 CH == CH.CHO + H_2O$$
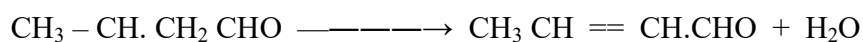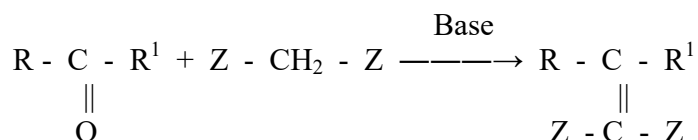
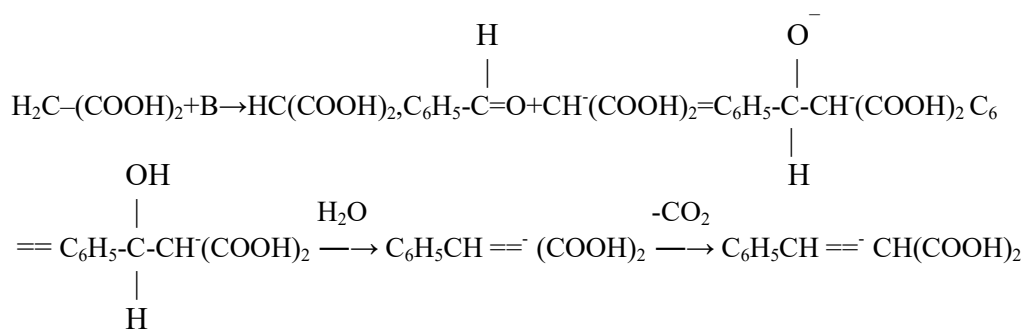**Aldol**   **Croton aldehyde**

The saturated Alcohols, δ, β, unsaturated Aldehyde ketones and unsaturated alcohols, sorbic acid are prepared by this method.

4.8.2 Knoevenagel Condensation

Condensation between aldehyde or ketones with compounds having active methylene group and base a catalyst (NH_3) giving unsaturated compounds.
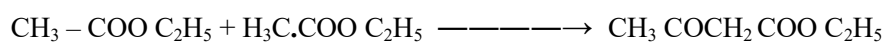
$$R - C - R^1 + Z - CH_2 - Z \xrightarrow{\text{Base}} R - C - R^1$$
$$\quad \| \qquad\qquad\qquad\qquad\qquad\qquad\qquad \|$$
$$\quad O \qquad\qquad\qquad\qquad\qquad\qquad Z - C - Z$$

A proton from the active methylene group to form carbonion which then adds on the carbonyl group of the aldehyde to form an adduct.

$$H_2C–(COOH)_2+B \rightarrow HC(COOH)_2, C_6H_5\text{-}C\overset{H}{=}O+CH^-(COOH)_2 = C_6H_5\text{-}\overset{O^-}{C}\text{-}CH^-(COOH)_2 \overset{}{\underset{H}{\big|}} C_6$$

$$== C_6H_5\text{-}\overset{OH}{\underset{H}{C}}\text{-}CH^-(COOH)_2 \xrightarrow{H_2O} C_6H_5CH ==^- (COOH)_2 \xrightarrow{-CO_2} C_6H_5CH ==^- CH(COOH)_2$$
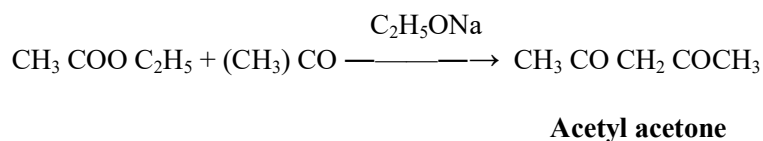
4.8.3 Claisen Condensation

The condensation of ester and H_2 containing ester ketone or nitrite to form a β – keto ester ketone or nitril respectively are Claisen Condensation. It is catalysed by Naethoxde, Sodamide etc. e.g. – C_2H_5ONa

$$CH_3 - COO C_2H_5 + H_3C.COO C_2H_5 \longrightarrow CH_3 COCH_2 COO C_2H_5$$

Ethyl acetate   **2 mole**   **Ethylacetone acetate**

$$CH_3 \, COO \, C_2H_5 + (CH_3) \, CO \xrightarrow{\quad C_2H_5ONa \quad} CH_3 \, CO \, CH_2 \, COCH_3$$

Acetyl acetone

It is carried out with a mixture of two different esters, each of which possess an α-hydrogen, a mixture of all four products is generally obtained and the reacting is seldom useful synthetically. However, if only one of the esters has an α-hydrogen, then the mixed reaction is frequently satisfactory. Among esters lacking α-hydrogens (hence acting as the substrate ester) that are commonly used in this way are esters of aromatic acids, and ethyl carbonate and ethyl oxalate. Ethyl carbonate gives malonic esters.
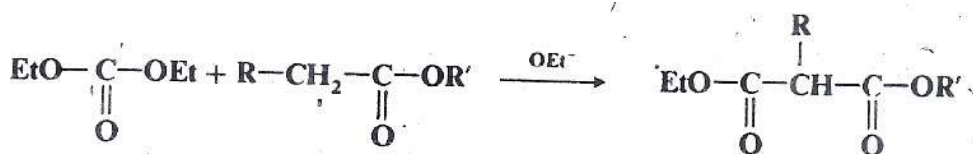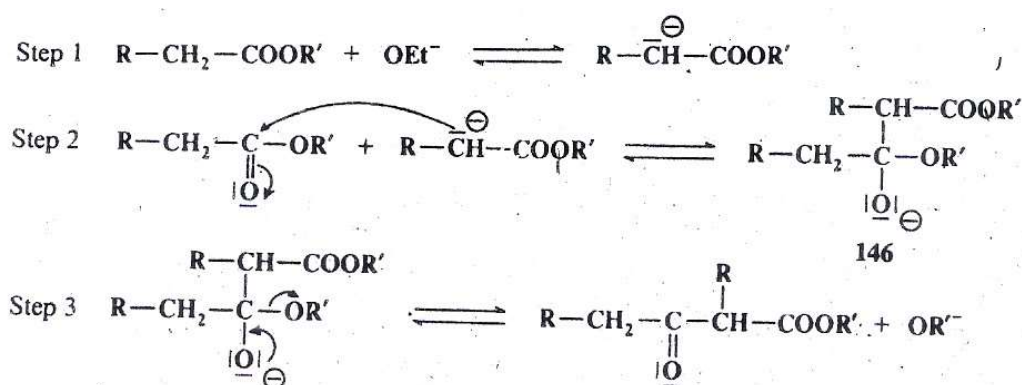

Ethyl formate serves to introduce the formyl group,
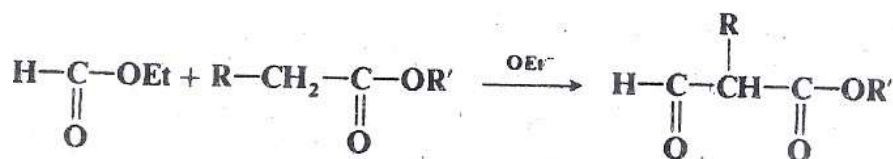
When the two ester groups involved in the condensation are in the same molecule the product is a cyclic β-keto ester and the reaction is called the Dieckmann condension.
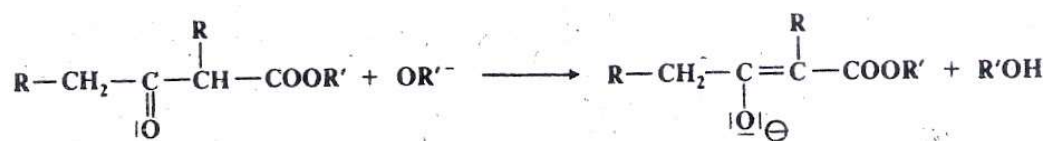

158
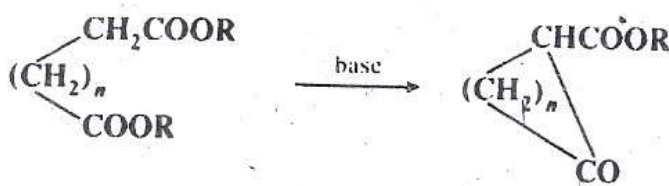
The mechanism of the Claisen and Dieckmann reactions is the ordinary tetrahedral mechanism, with one molecule of ester being converted to a nucleophile by the base and the other serving as the substrate.

Step 1 $R-CH_2-COOR' + OEt^- \rightleftharpoons R-\overset{\ominus}{C}H-COOR'$

Step 2 $R-CH_2-\underset{|\underline{O}|}{\overset{\|}{C}}-OR' + R-\overset{\ominus}{C}H-COOR' \rightleftharpoons R-CH_2-\underset{|\underline{O}|^{\ominus}}{\overset{R-CH-COOR'}{\underset{|}{C}}}-OR'$

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Step 3 $R-CH_2-\underset{|\underline{O}|^{\ominus}}{\overset{R-CH-COOR'}{\underset{|}{C}}}-OR' \rightleftharpoons R-CH_2-\underset{|\underline{O}}{\overset{\|}{C}}-\overset{R}{\underset{|}{C}}H-COOR' + OR'^-$

This reaction illustrates the striking difference in behaviour between esters on the one hand and aldehydes and ketones on the other. When a carbonion such as an enolate ion is added to the carbonyl group of an aldehyde or ketone, the H or R is not lost, since these groups are much poorer leaving groups than OR. Instead the intermediate adds a proton at the oxygen to give a hydroxy compound.

In contrast ordinary esters ract quite well, that is, tow Z groups are not needed. A lower degree of acidity is satisfactory because it is not necessary to convert the attacking ester entirely to its ion. Step 1 is an equilibrium that lies well to the left. Nevertheless, the small amount of enolate ion formed is sufficient to attack the readily approachable ester substrate. All the steps are equilibria. The reaction proceeds because the product is converted to its conjugate base by the base present (that is, a β-keto ester is a stronger acid than an alcohol) :

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$$R-CH_2-\underset{\underset{\underset{\ominus}{|O|}}{||}}{C}-\underset{\underset{H}{|}}{\overset{\overset{R}{|}}{C}}-COOR' + OR'^- \longrightarrow R-CH_2-\underset{\underset{\underset{\ominus}{|O|}}{|}}{C}=\overset{\overset{R}{|}}{C}-COOR' + R'OH$$

The use of stronger base, such as sodium amide, sodium hydride, or potassium hydride, often increases the yield. For some esters stronger bases must be used, since sodium ethoxide is ineffective. Among these are esters of the type $R_2CHCOOEt$, the products of which ($R_2CHCOCR_2COOEt$) lack an acidic hydrogen, so that they cannot be converted to enolate ions by sodium ethoxide.
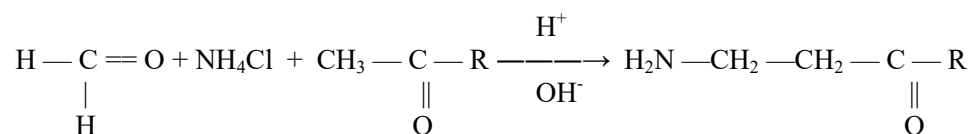

Check your progress – 2

Notes :- 1. Write your answers in the space given below.
       2. Compare your answers with ones given at the end of the unit.

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   a) Witting Reactions
   b) Michael Reactions
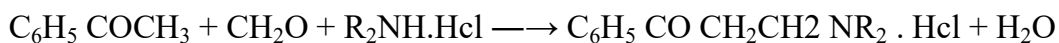   c) Claisen Condensation
   d) Addition to Grignard Reagent

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4.8.4 Mannich Condensation

The condensation between a coumpound containing atleast one active H_2 atom, form aldelyde and NH_3, primary or secondary amine, the net change –

$$\underset{\underset{H}{|}}{H-C}=O + NH_4Cl + CH_3-\underset{\underset{O}{||}}{C}-R \xrightarrow[OH^-]{H^+} H_2N-CH_2-CH_2-\underset{\underset{O}{||}}{C}-R$$

   Or

$C_6H_5 COCH_3 + CH_2O + R_2NH.Hcl \longrightarrow C_6H_5 CO CH_2CH2 NR_2 . Hcl + H_2O$
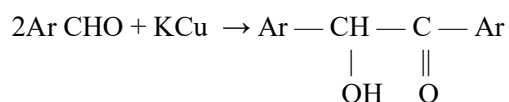
During the reaction is the replacement of the active H_2 atom by an Aminomethyl group or substituted Amino-methyl group. Ketones, Acids and their esters phenols, furan, pyrrole and their derivatives, acetylene and methylated pyridines etc. are the major reactants in this condensation.

4.8.5 Benzoin-Aldehyde Condensation

$$2Ar\,CHO + KCu \rightarrow \underset{\underset{OH}{|}\;\;\underset{O}{\|}}{Ar\!-\!CH\!-\!C\!-\!Ar}$$
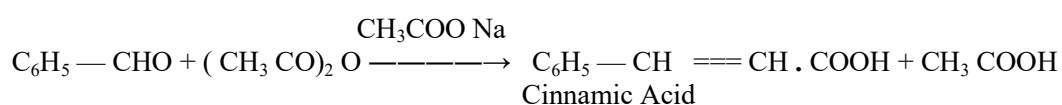
When certain Aldehydes are treated with cyanide ion benzoin are produced, involving addition of one molecule of Aldehyde to $C == O$ group of another. This is for Aromatic Aldehydes.

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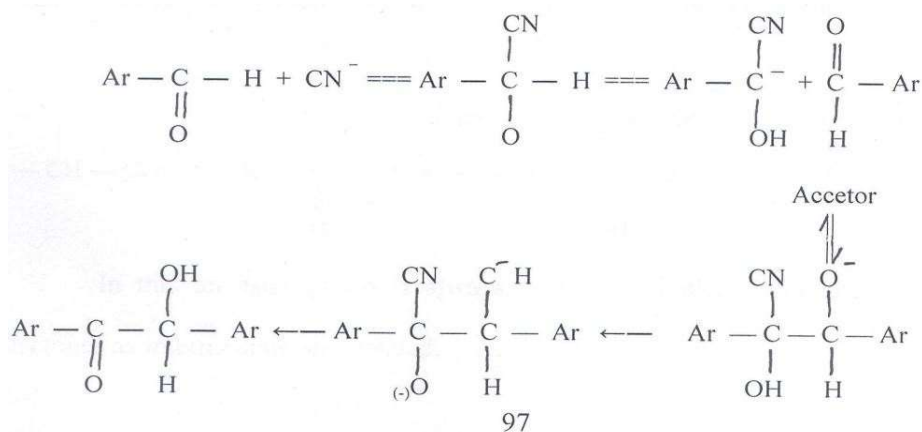
CN can act as nucleophilic, electron withdrawing (loss of Aldehyde Proton) and finally as leaving group.

4.8.6 Perkins Reaction

In condensation of an Aromatic Aldehyde and Aliphatic acid, an hydride containing atleast two δ H_2 atom e.g. $(RCH_2CO)_2$ O in the presence of Na or K salts of the corresponding acids to form δ, β unsaturated acid known as **Perkin Reaction**.

$$C_6H_5 — CHO + (CH_3 CO)_2 O \xrightarrow{CH_3COO\ Na} \underset{\text{Cinnamic Acid}}{C_6H_5 — CH} === CH . COOH + CH_3 COOH$$

4.8.7 Stobbs Reaction

Drathyl succinate and its derivatives condesnses with aldehyde ketones in base. Thus Na OE$^+$ (Naethoxide) etc. is called **Stobbs Condensation**.
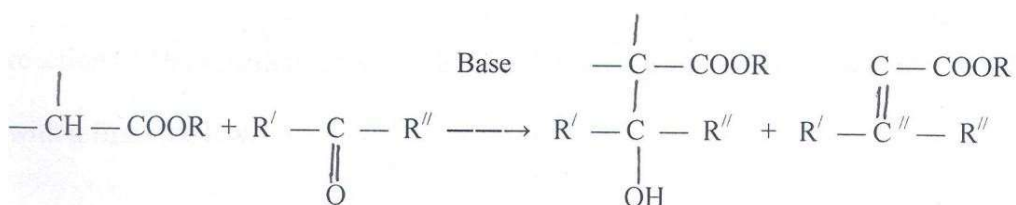
In this an ester group is always cleaved and olefins are the product and lactones as intermediate are isolated.

In the presence of a strong base, the α-carbon of an ester can condense with the carbonyl carbon of an aldehyde or ketone to give a β-hydroxy ester, which may or may not be dehydrated to the α, β-unsaturated ester.
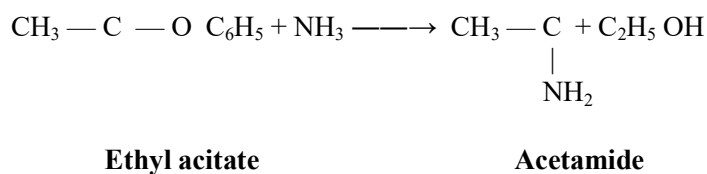
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Besides ordinary ester (containing an α-hydrogen), the reaction can also be carried out with lactones and, with the γ position of α, β-unsaturated esters (vinylology).

For most esters, a much stronger base is needed than for aldol condensations; (i-Pr)$_2$ NLi, Ph, CNa and LiNH$_2$ are among those employed. However, one type of ester reacts more easily, and such strong bases are not needed : diethyl succinate and its derivatives condense with aldehydes and ketones in the presence of bases such as NaOEt, NaH, or KOCMe$_3$. This reaction is called the Stobbe condensation. One of the ester groups (sometimes both) is hydrolyzed in the course of the reaction. The following mechanism accounts for (1) the fact that succinic esters react so much better than others; (2) one ester group is always cleaved; and (3) the alcohol is not the product but the olefin. In addition, intermediate lactones have been isolated from the mixture.

4.9   HYDROLYSIS OF ESTERS

The Esters mentioned in previous reactions can be hydrolysed to alcohols. When Vinylic substrate is hydrolysed, the products are aldehydes or ketones. Esters of in acids on hydrolysis give aldonols. The treatment ester with NH$_3$ in ethyl alcohol, gives Amide. This involves nucleophilic attack by a base (NH$_3$) on the electron deficient carbon, Alkoxy group or is replaced by NH$_2$.

$$O$$
$$\parallel$$

$$CH_3 — C — O\ C_6H_5 + NH_3 \longrightarrow CH_3 — C\ + C_2H_5\ OH$$

$$\underset{NH_2}{|}$$

Ethyl acitate   **Acetamide**

4.9.1 Elimination Reaction

The E_1 mechanism requires that the reactant be placed in an ionizing solvent unlike the E_2, C – H & C – X bonds break in two separate steps. First, a Heterolysis of the C – X bond takes place to form a carbocation followed by loss of proton from β – position to yield Alkene. The intermediate carbocation is the same as that in SN_1 reactions. The reaction does not require the presence of any reagent and is consistent with a first rate law.
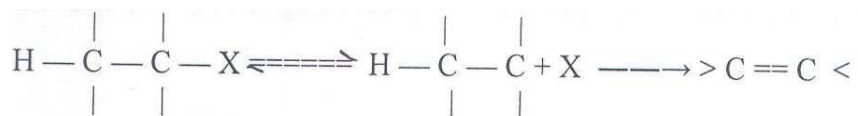

In E_2 mechanism, a base is needed for the reaction to take place. An atom, often a H_2 atom, is pulled from the β – position and the leaving group departs from the δ – position. The removal of proton and rupture of the C – X bond takes place in a single step without any intermediate formation approximate nature of the transition state is as bi-molecular process, the rate is proportional to the concentration of the both reactants. This is the most common **Elimination Reaction**.
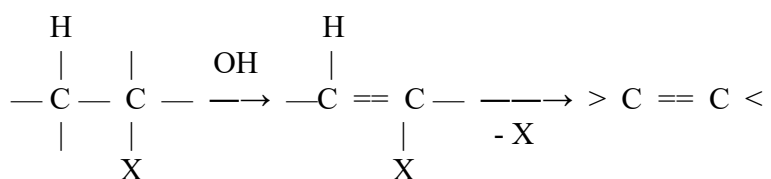
The abstraction of proton and the loss of the leaving group take place in a single step. Hence the rate determining and the product formation steps are identical. Analogous to SN_2 reaction the base may be neutral or negatively charged.

4.9.2 ELCB Mechanism

This is consistent with second order rate law of equation and involves two steps like E_1 Mechanism, but C – H initially ruptures to form an intermediate carbonion and the process is completed by the subsequent loss of the leaving group called ElcB (Elimination from conjugated base) thus two stage process and the carbon ion is formed in a pre-equilibrium step. The proton is transferred completely to the base in transition state.
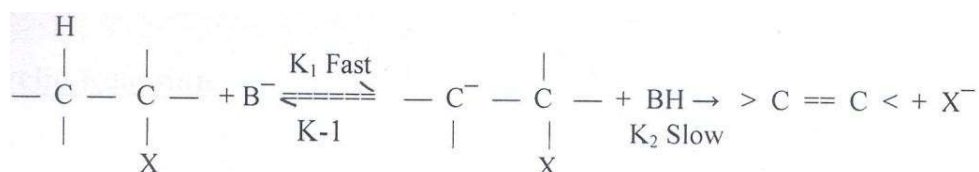
In this mechanism the overall rate of the reaction is limited to the slower second step whose rate depends only on the concentration of the conjugate base of the alkylhalide. Because of this, the mechanism is referred to as ElcB mechanism (Eliminatino Unimolecular Conjugate Base). The problem is how to decide which of the two mechanism is operating? This has been done by isotopic labelling experiments. Let us consider the formation of styrene by the action of ethoxide on 2-phenylethyl bromide. This reaction follows second order kinetics.

4.9.3 Effect of Substrate Structure

This determines elimination versus substitution, gives clearer substrate structure. The role of structural effects had been deduced in terms of steric and electronic

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consideration. The yield of substitution reaction is retarded by branching a δ position or β-carbon atoms, but branching at accelerated elimination due to great hyper conjugative inter action of the forming double bond.   In alkene, yield is much lower in uni-molecular than in bi-molecular reaction. The nature of leaving group also influences the course of elimination reaction. The case of displacement follows the order Br > Cl> NMe so that change from a good to poor leaving group definitely alter the transition state. The response to inductive effect increases in order Br < OTs < SMe$_2$ and I < Br < Cl < F for halides. Poor leaving groups thus favour an ElcB transition state. The base is an essential in all bi-molecular elimination.

In acyclic system in which E$_2$ elimination is favoured, when approximate groups are trans to each other. The reaction is stereo-spacific i.e. erythro eliminates to give CIS & thero gives trans alkene respectively.

LET US SUM UP

The addition to C-C multiple bonds, Syn & Anti Addition, Neucleophilic & Free Radical Reactions are explained. The Orientation reactivity with examples is explained with effect of substrate structures.

CHECK YOUR PROGRESS – 1 – THE KEY

   a)   4.7 – Addition to Carbon-Hetero Multiple Bond.

   b)   4.3 –   Orientation and Reactivity

   c)   4.2.3 - Neucleophilic addition

CHECK YOUR PROGRESS – 2 – THE KEY

a)   4.8 -   Witting Reactions.

b)   4.5 –   Michael Reactions

c)   4.8.3 –   Claisen Condensation

d)   4.7.1 –   Addition to Grignard Reagent.

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UNIT – V : PERICYCLIC REACTION

Structure

5.0   INTRODUCTION

Various compounds are influenced by polarity. In organic molecules, reactions proceed either polar path way or free radical path way and are known as concerted reactions. They are unaffected by catalysts or solvents, as in Diel's & Aldes and Woodward & Hoffman Reaction. In pericyclic compounds, Elimination and rearrangement reactions are also observed for conversion of compounds in presence of heat.

5.1   OBJECTIVE

The various reactions in benzene ring or in aliphatic compounds with conjugation o9r elimination are given with examples of the Scientists'.

5.2   PERICYCLIC REACTION

Majority of organic reaction proceed either through polar path way or free radical path way. The polarity influenced by change in the polarity of the salt & radical path way by radical initiation. Many reactions are not influenced by polarity or free radical initiators. Such reactions are called concerted i.e. they occur in one step processes involving rearrangements of electrons for breaking and making of bond simultaneously. Therefore, these should not be radical or ionic intermediate (concerted) and the reaction is attended by degree of stereoselectivity. There is no involvement of electrophilic or Nucleophilic reagent and the transient state is cyclic with reversible and none affected by solvent or catalyst.

Therefore, pericyclic reactions are concerted reaction unaffected by catalyst or solvents neither nucleophilic nor electrophilic reagents are involved and have cyclic transition states. The concerted reaction unaffected by catalysts or solvents and are converted into product without an intervention of an intermediate and formation. Where the formation and breaking of bonds occur simultaneously e.g. **Diel's & Alder**

**Reaction** involving 1, 4 additions of substituted alkenes to conjugated (System) dienes.

According to **Woodward & Haffman**, the rational explanation for the above statement was offered as which status that orbital symmetry is conserved in concerted reactions.

Electrocyclic Reaction is a type of pericyclic which involves the formation of a ring, with the generation of one sigma bond and lose of one π bond or ring is broken with the opposite concequence. The reaction is completely stereospecific and exact stereo-chemistry depends upon two factors (1) no. of double bond in polyene and (2) whether the reaction is thermal or photochemical e.g. cyclobutene system opens to give 1, 3 butadiene.

CIS   CIS - Trans
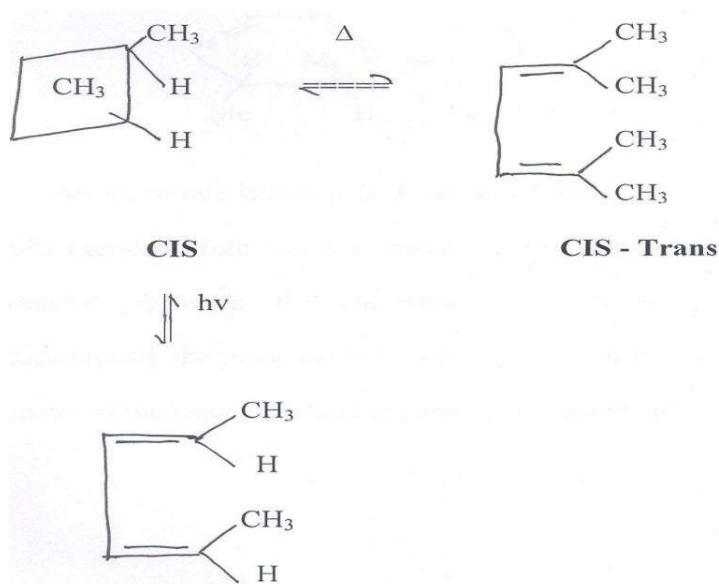
A sigma bond in cyclobutene must to yield the open chain diene. This bond break in two ways (1) con-rotatory process, the two orbitals of sigma bonds rotates either clockwise or anti-clockwise as obtains under thermal conditions.

All these reactions are inaccurate to infer all electrocyclic reaction to go in a con-rotatory manner under thermal conditions and in a dis-roratory manner under therman conditions and in a dis-rotatory mode or irradiation e.g. irradiation of trans, CIS, Trans-1, 6 dimethylhexa-1, 3- triene (I) to give trans-5, 6 dione ethylecyclohexa-1, 3 diene (II) while thermal ring closure lead to CIS-5, 6-dimethylcyclohexa-1, 3 diene (III) .
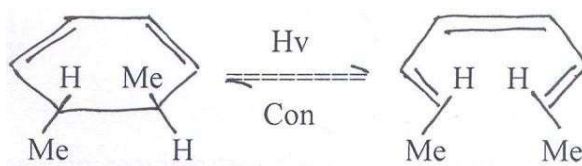
An electronic reaction is a concerted and cyclic process in which reactant orbitals