GOVERNMENT ARTS AND SCIENCE COLLEGE,
PALKULAM, KANYAKUMARI-629 401

STUDY MATERIAL FOR B.Sc. CHEMISTRY
ORGANIC CHEMISRTY

SEMESTER - VI

ACADEMIC YEAR 2022 – 2023

PREPARED BY

DEPARTMENT OF CHEMISTRY (SF)

UNIT	CONTENT	PAGE N0.
I	CARBOHYDARATES	03
II	PHENOLS, AROMATIC ALDEHYDES, KETONES AND ACIDS	11
III	REARRANGEMENTS	19
IV	TERPENOIDS AND ALKALOIDS	28
V	ORGANIC SPECTROSCOPY	46

UNIT - I

CARBOHYDRATES

Mutarotation

Definition:

The change in specific rotation of an aqueous solution of a monosaccharide to an equilibrium value known as mutarotation. All reducing sugars (except some ketoses) undergo mutarotation.

Example:

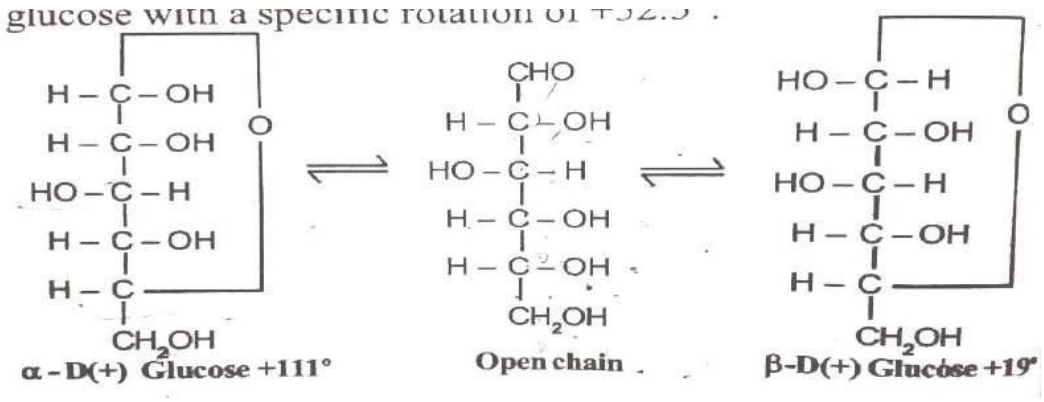
Freshly prepared solutions of glucose crystallised from cold ethanol (a-D-glucose) have a specific rotation of +111°. When this solution is allowed to stand, the specific rotation falls to+52.5°. Similarly a freshly prepared solution of glucose crystallised from hot pyridine (b-D-glucose) has a specific rotation of +19°. When this solution is allowed to stand, the specific rotation rises to +52.5°. The α and β forms of glucose equilibrate to a mixture with a constant specific rotation (+52.5°).

A-D (+) Glucose ↔ Equilibrium mixture ↔ β- D (+) Glucose

+111° +52.5° +19°

Mechanism:

The mechanism of mutarotation involves the opening and closing of the ring structure. H2O acts as the catalyst. The two forms undergo tautomeric change and yield an equilibrium mixture of 36% α-D(+)glucose and 64% β-D(+) glucose with a specific rotation of+52.5°.



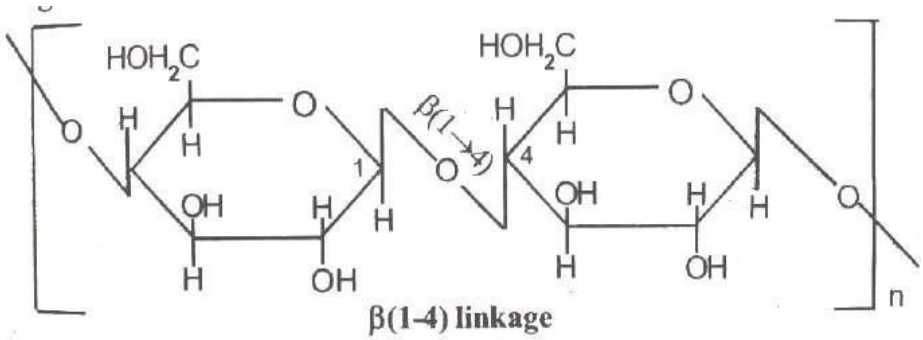
Fisher and Haworth's structure of ribose.

The chair form of ribose follows a similar pattern as that for glucose with one exception. Since ribose has an aldehyde functional group, the ring closure occurs at carbon # 1, which is the same as glucose.

The exception is that ribose is a pentose, five carbons. Therefore a five membered ring is formed. The -OH on carbon #4 is converted into the ether linkage to close the ring with carbon hi#1. This makes a 5 member ring – four carbons and one oxygen. Carbon # 1 is now called the numeric carbon and is the center of a hemiacetal functional group. A carbon that has both an ether oxygen and an alcohol group is a hemiacetal.

Haworth's structure of Cellulose:

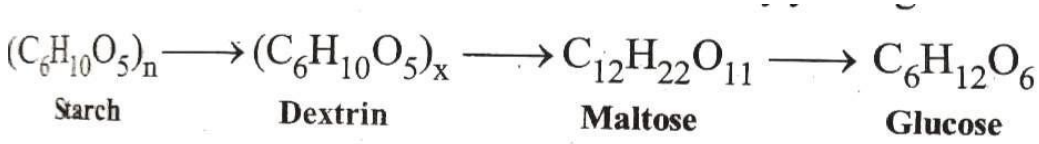
On complete hydrolysis it gives glucose. Enzymatic hydrolysis of cellulose gives cellobiose, a disaccharide with β (1 → 4) glycosidic linkage. This proves that cellulose is a linear polymer having β-D-glucopyranose units joined by β-(1 → 4) linkages.



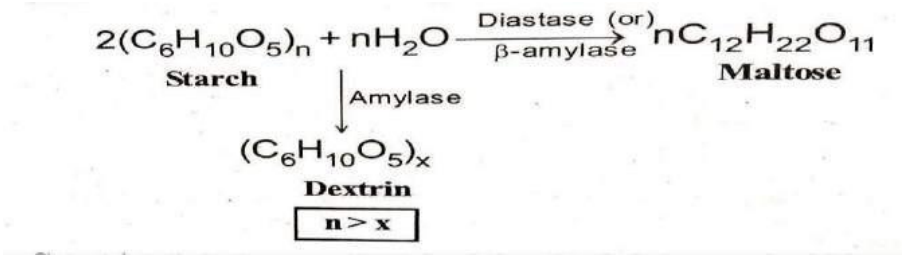
β(1-4) linkage

Properties of starch

- It is white, amorphous substance with no taste or smell.
- Insoluble in cold water but with boiling water it forms a colloidal, translucent suspension.
- When heated to 200-250°C it changes in to dextrin. At higher temperature charring takes place.
- Starch when boiled with dilute acid, ultimately.
- It is hydrolyzed by enzymes amylase and diastase into dextrin and maltose respectively.



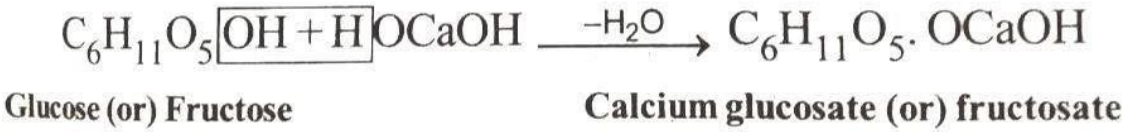
$n > x$

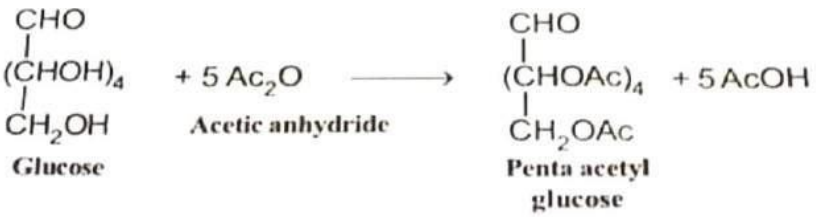


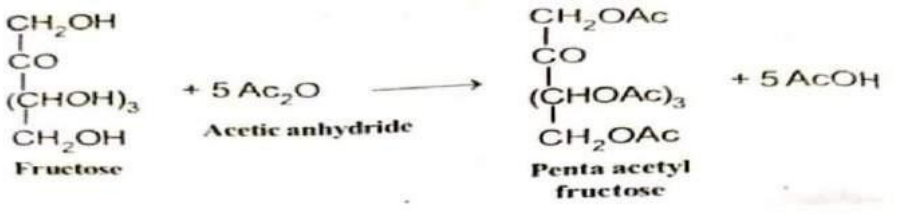
- Starch gives a blue colour with a drop of iodine. It is only a - amylose that gives a blue colour with iodine. Amylopectin gives a reddish brown colour with iodine.
- When heated with a mixture of concentrated sulphuric acid and nitric acid it gives nitro starch.

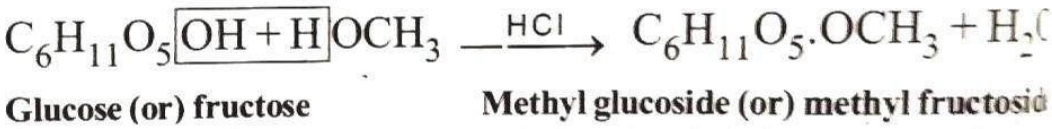
Reaction of Glucose and Fructose

- Acidic character: Both glucose and fructose behave as weak acids and form salts with $Ca(OH)_2$.
- Ester formation: Glucose and fructose form penta acetyl derivative where treated with acetican hydride.





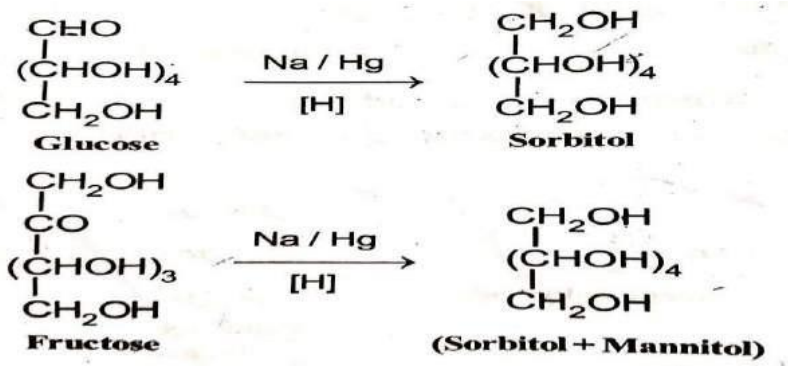


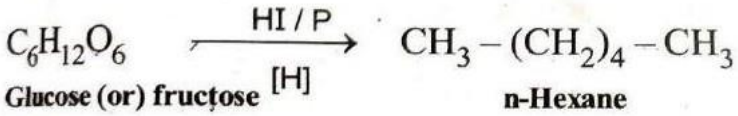


i) Ether formation: Glucose and fructose react with methanolin the presence of dry HCl gas to give ether known as methyl glucoside and methyl fructoside respectively.

Reduction:

Sodium amalgam reduces glucose into sorbitol and fructose into a mixture of sorbitol and mannitol. Both are reduced to n-hexane by HI/red P.

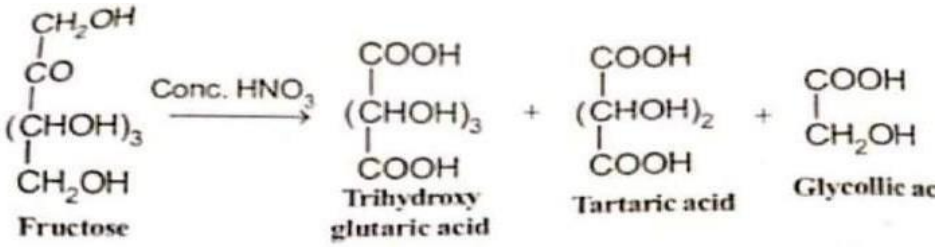




Oxidation:

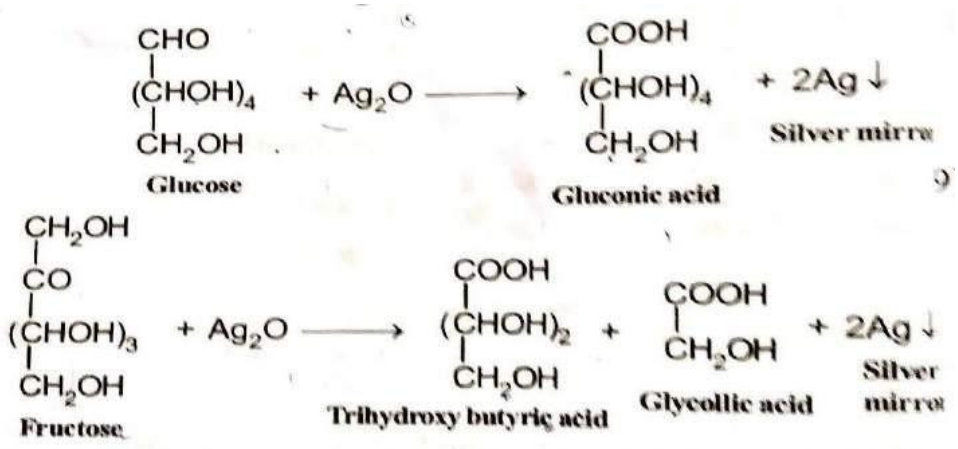
Glucose is oxidized by mild oxidizing agents like bromine water into gluconic acid Strong oxidizing agents like concentrated HNO_3 oxidize glucose into glucaric acid.

Fructose is not oxidized by mild oxidizing agents. But strong oxidizing agents like concentrated HNO_3 split fructose into a mixture of tri hydroxy glutaric, tartaric and glycollic acid.



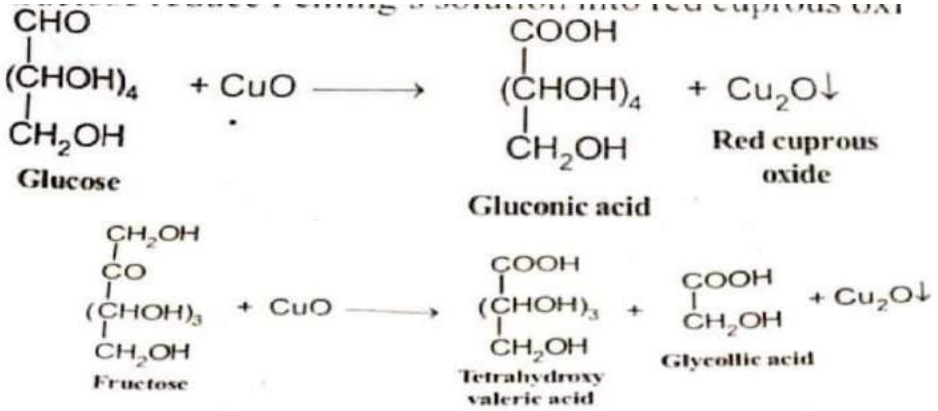
Action with Tollen's reagent:

Both glucose and fructose reduce Tollens reagent into silver mirror



Action with Fehling's solution:

Both glucose and fructose reduce Fehling's solution into red cuprous oxide.



Action with Barfoed's and Benedict's reagents:

Both glucose and fructose reduce Barfoed's and Benedict's reagents into red cuprous oxide as in the case of Fehling's solution.

Glucose + CuO → Gluconic acid + Cu_2O

Fructose + CuO → Tartaric acid + Glycollic acid

Since both glucose and fructose reduce all these four reagents (Tollen's, Fehling's, Benedict's and Barfoed's reagents). These sugars are known as reducing sugars.

Specific rotation of glucose and fructose:

Glucose is dextrorotatory. Hence known as dextrose. Specific rotation of α-D(+)glucose is +111° : specific rotation of β-D(+)glucose is 19°. Equilibrium value is +52.5°. Fructose is laevorotatory. Hence known as levulose.

Specific rotation of α-D(-) fructose is -21°:specific rotation of β-D(-)fructose is-133°:Equilibrium value is -92°.

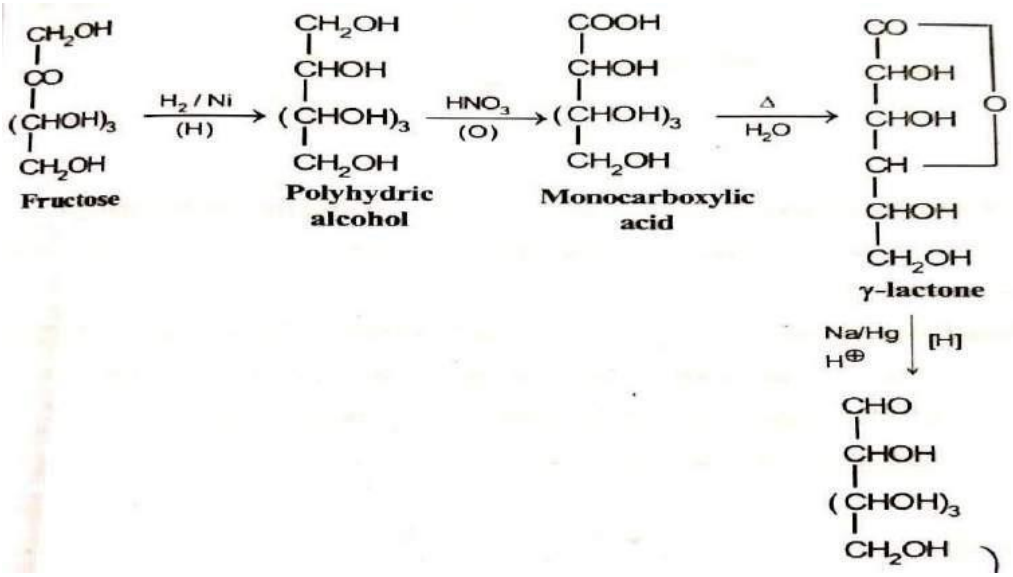
Optical isomers of glucose and fructose:

Glucose contains four asymmetric carbon atoms and hence it gives rise to (2^4) 16 optical isomers. Fructose contains 3 asymmetric carbon atoms and hence it gives rise to (2^3) 8 optical isomers but only six are known.

Conversion of glucose into fructose and fructose into glucose:

Glucose is converted to glucosazone on treatment with excess of phenylhydrazine. Osazone on hydrolysis with HCl gives osone. On reduction with Zn/CH_3COOH osazone gives fructose as follows.

Fructose on catalytic reduction gives polyhydric alcohol which on oxidation with HNO_3 gives mono carboxylic acid. The acid on heating gives γ-lactone which on reduction with Na/Hg gives glucose as follows.



Cellulose

It is a homo polymer of β -D - glucose. It is the main constituent of the cell wall of the plants. Plants maintain their structure due to the support of fibrous material cellulose. Cotton, jute, hemp, wood, papers are some of the different forms of cellulose.

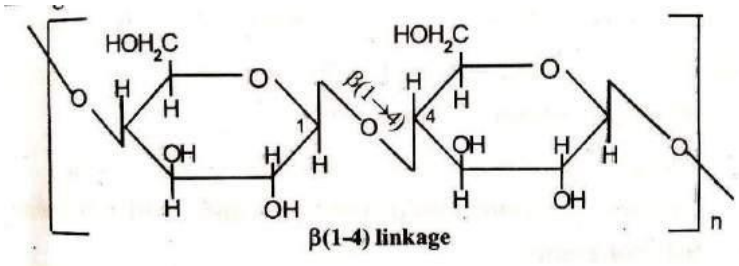
Properties of cellulose

- It is a white, amorphous solid, insoluble in water.
- It is soluble in ammoniacal solution of cupric hydroxide.
- When treated with conc. H_2SO_4 in the cold it passes into solution. This solution on dilutionwithwater gives a starch-like substance amyloid.
- Whenboiled with dilute H_2SO_4 it is hydrolysed into glucose.

  $(C_6H_{10}O_5)n + nH_2O \rightarrow nC_6H_{12}O_6$
  Cellulose glucose
- It forms hydrocellulose with dil.acid and water.
- Cellulose on nitration with the mixture of conc. HNO_3 and conc.H_2SO_4, forms mono, di and trinitrates of cellulose
- Cellulose on acetylation gives a mixture of di and tri acetates of glucose.

Haworth's structure of cellulose:

On complete hydrolysis it gives glucose. Enzymatic hydrolysis of cellulose gives cellobiose a disaccharide, with (1→4) glycosidic linkage. This proves that cellulose is the linear polymer having β-D-glucopyranose units



joined by β(1→4) linkages.

Uses of cellulose and its derivatives:

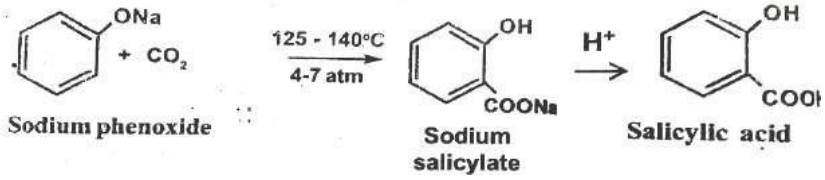
- Cellulose as such is used in the manufacture of paper and clothes.
- Gun cotton, the completely nitrate cellulose, is used in the manufacture of explosives such as blasting gelatin and cordite.
- Pyroxylin, the lower cellulose nitrate is used in medicines, photography, paints and lacquers.
- Celluloid, a mixture of camphor and pyroxylin in alcohol is used for making toys, ornamental articles, photo graphic films etc.,
- Cellulose xanthate, obtained by the reaction of wood pulp with carbon disulphide and NaOH is a basic material for viscose rayonyarn.
- Cellulose acetate is used for making safety tube photographic film, motion picture film etc.,
- Cellophane is used as protecting film.

UNIT – II

PHENOLS, AROMATIC ALDEHYDES, KETONE AND ACIDS

1. Kolbe's Reaction:

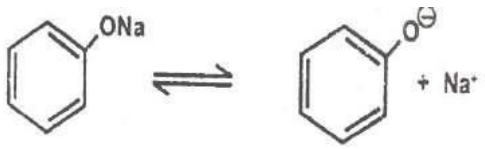
When sodium peroxide is heated with carbon dioxide, under pressure, sodium salicylate is formed. The product on acidification yields salicylic acid. This is called Kolbe-Schmidt reaction (or) Kolbe's Reaction.



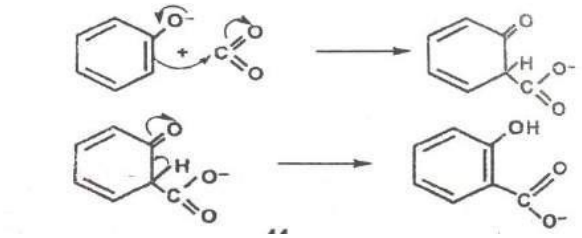
Mechanism:

The Kolbe reaction is an eletrophile substitution reaction. The slightly electron deficient carbon of CO_2 attacks the o or p-positions.

i. Formation of phenoxide ion:



ii. Attack of CO_2 to the ring at o or p-position:

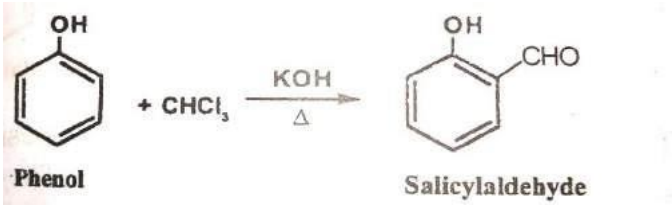


iii. Hydrolysis:

The o-isomer is formed predominantly as the intermediate is stabilised due to chelation through intramolecular H-bonding.

2. Reimer-Tiemann reaction:

When phenol is refluxed with chloroform and alkali at 60 C, o - hydroxy benzal dehyde is obtained as the major product. This is called Reimer-Tiemann reaction.



Mechanism:

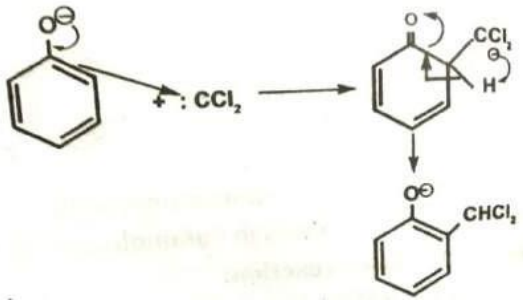
Generation of electrophile, di-chloro carbene: CCl2

$CHCl_3 + OH^{(-)} \rightarrow CCl_3 + H_2O$

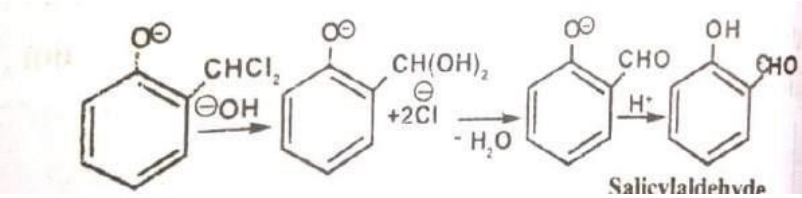
CCl3 :$CCl_3 + Cl^{(-)}$

i. rmation of Peroxide ion

ii. lectrophonic attack by :CCl_2



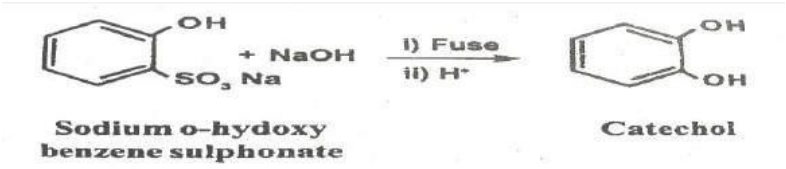
iii. Hydrolysis :



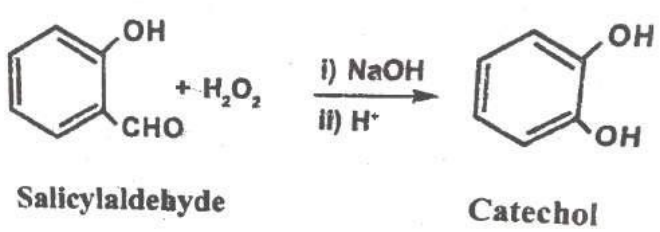
iv. Catechol:

Preparation:

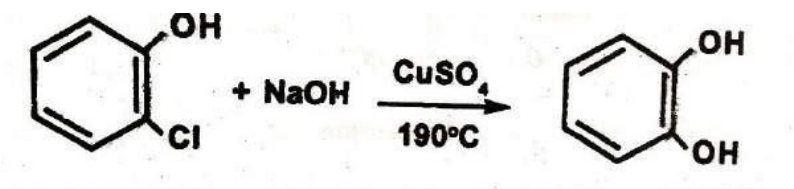
a) y alkali fusion of sodium o-hydroxy benzene sulphonate



b) the action of alkali H2O2 on salicylaldehyde (taken reaction)



c) By heating o-chlorophenol with aqueous NaOH in presence of the traces of CuSO4 at 190 C.



v. Vanillin (p-hydroxy-m-methoxy benzaldehyde)

Occurrence:
Vanillin occurs in vanilla bean.

Preparation:

a) It may be prepared synthetically from guaiacol by Reimer-Tiemann reaction.

b) It is prepared industrially by oxidizing is oeuginol with nitrobenzene.

Uses:
Vanillin (2.5 percent ethanolic solution) is used as a flavour in ice-creams, chocolate, candy, bakery products and perfumery.

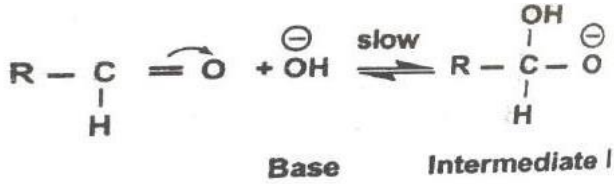
vi. Cannizaro reaction:

Definition:
In the presence of conc. Alkali, aldehydes containing no a-hydrogen undergo self-oxidation-reduction to give a mixture of an alcohol and a salt of carboxylic acid. The reaction is known as Cannizaro's reaction.

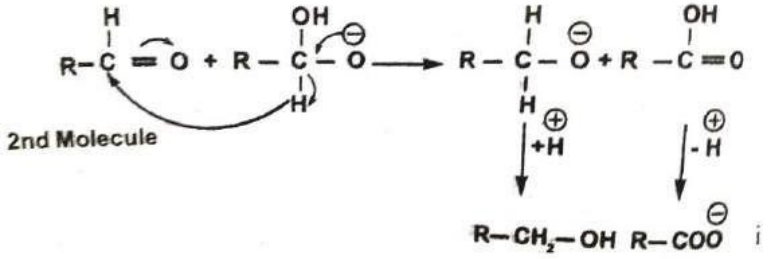
$2R - CHO \rightarrow R - CH_2 - OH + RCOO\ Na$
Alcohol Sodium Carboxylate

Example:

Benzaldehyde undergoes Cannizaro's reaction in the presence of 50% NaOH to give a mixture of benzyl alcohol and sodium benzoate.
$2C_6H_5CHO \rightarrow C_6H_5\text{-}CH_2OH + C_6H_5COONa$
Benzaldehyde Benzyl alcohol Sodium benzoate
Mechanism:
Step: 1
Attack to nucleophile on the carbonyl carbon to form intermediate I:



Step: 2
Addition of hydride ion from intermediate I to the carbonyl carbon of second molecule of aldehyde.

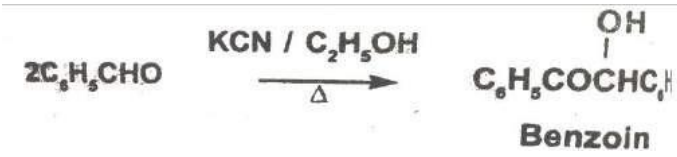


vii. Benzoic Condensation:

Definition:

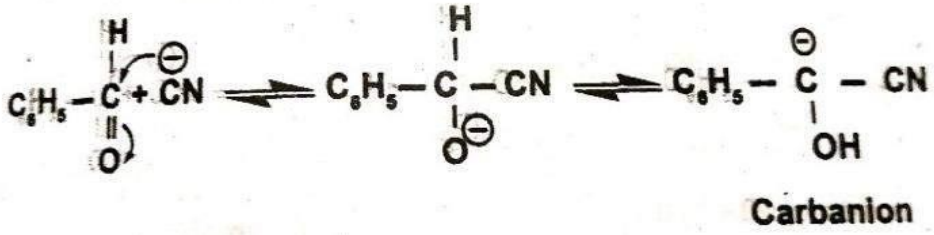
In the presence of alkali cyanides, aromatic aldehydes dime rise to form a - hydroxy ketones, called benzoins. The reaction is called benzoin condensation.

Example: Benzaldehyde in the presence of ethanol KCN, gives benzoin.

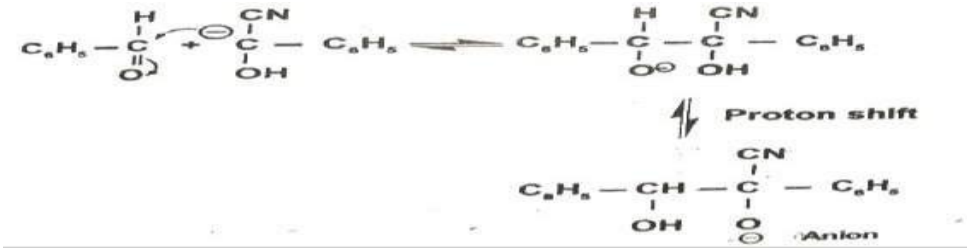


Mechanism:

1. Addition of $CN^{(-)}$ to the carbonyl group followed by proton transfer to yield a carbanion.



2. Addition of carbanion to the carbonyl carbon of another molecule of Benzaldehyde to form an anion.



Removal of CN^- from the anion gives benzoin.

Benzoin

viii. Claisen's reaction:

Definition:

It is the condensation reaction between an aromatic aldehyde and a aliphatic aldehyde or ketone having a-hydrogen atoms in the presence of dilute alkali to form unsaturated aldehyde or ketone.

Example: Benzaldehyde on Claisen's reaction with acetaldehyde gives cinnamaldehyde.

C_6H_5-CH_2OH + CH_3CHO → C_6H_5-CH=CH-CHO + H_2O

Benzaldehyde Acetaldehyde Cinnamaldehyde

Mechanism:

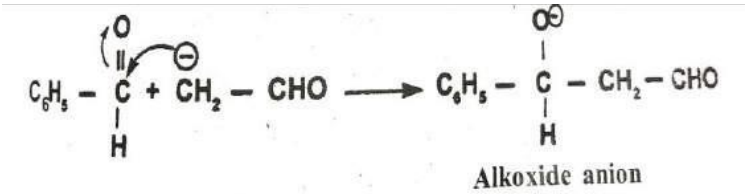
Step: 1

Formation of carbanion

$HO^{(-)}$ + H-CH_2-CHO →$^{(-)}$ CH2-CHO + H2O

Step: 2

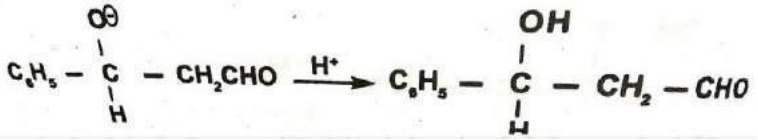
Addition of carbanion to the carbonyl group of the Benzaldehyde to give alkoxide anion



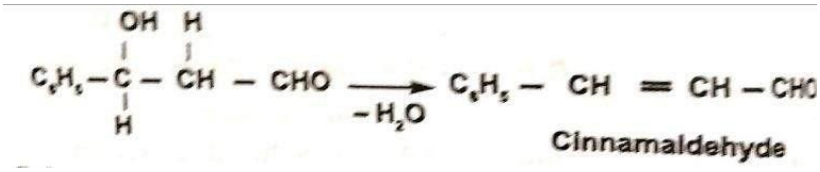
Alkoxide anion

Step: 3

Protonation of the alkoxide anion to give an aldol



Step:4 Dehydration of the aldol to give cinnamaldehyde



ix. Perkin's reaction:

Definition:

Condensation of aromatic aldehyde with acid anhydride in the presence of the anion of the acid is called Perkin's reaction or Perkin's condensation.

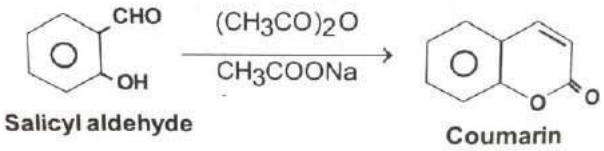
Example:

Benzaldehyde on Perkin's reaction with acetic anhydride gives cinnamon acid.

$C_6H_5CHO + (CH_3CO)_2O \rightarrow C_6H_5\text{-}CH = CH\text{-}COOH + CH_3COOH$

Benzaldehyde **Cinnamic acid**

Salicylaldehyde on Perkin's reaction gives coumarin



Mechanism:

Step: 1

Formation of carbanion of acetic anhydride

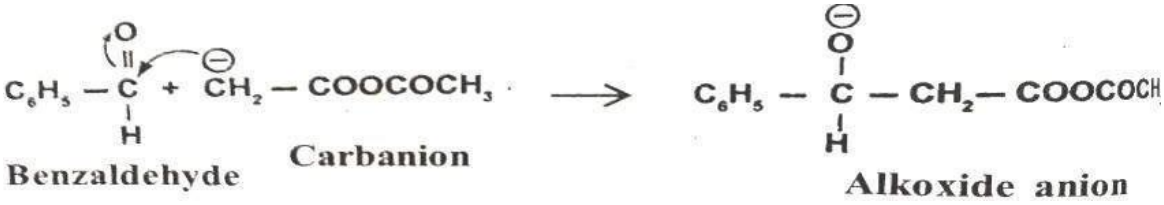
$CH_3COONa \rightarrow CH_3COO^{(-)} + Na^{(+)}$

$CH_3COO^{(-)} + CH_3\text{-}CO\text{-}O\text{-}CO\text{-}CH_3 \rightarrow {}^{(-)}CH_2\text{-}CO\text{-}O\text{-}CO\text{-}CH_3 + CH_3COOH$

Carbanion

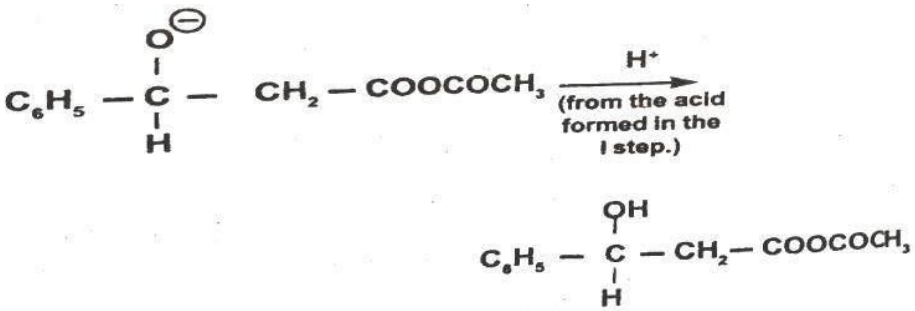
Step: 2

Addition of car anion to the carbonyl group Benzaldehyde to give alkoxide anion



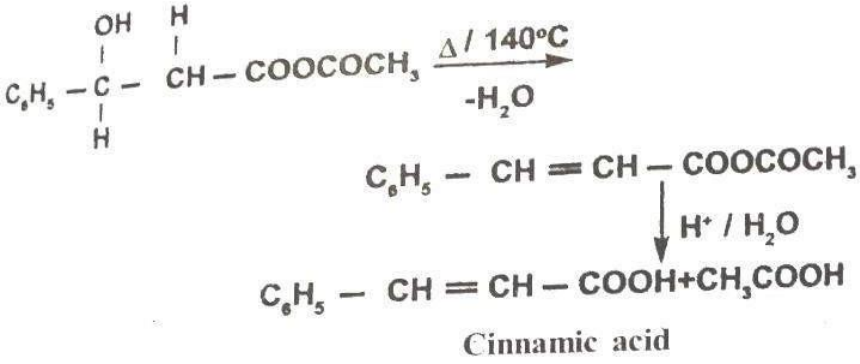
Step: 3

Protonation of the alkoxide to give an aldol-like product



Step: 4

Dehydration of the aldol-like product followed by hydrolysis to give Cinnamic acid.



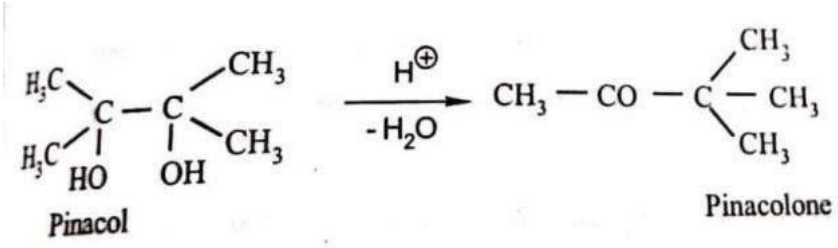
UNIT – III

REARRANGEMENT

1. Pinacols - Pinacolone rearrangement:

Definition:

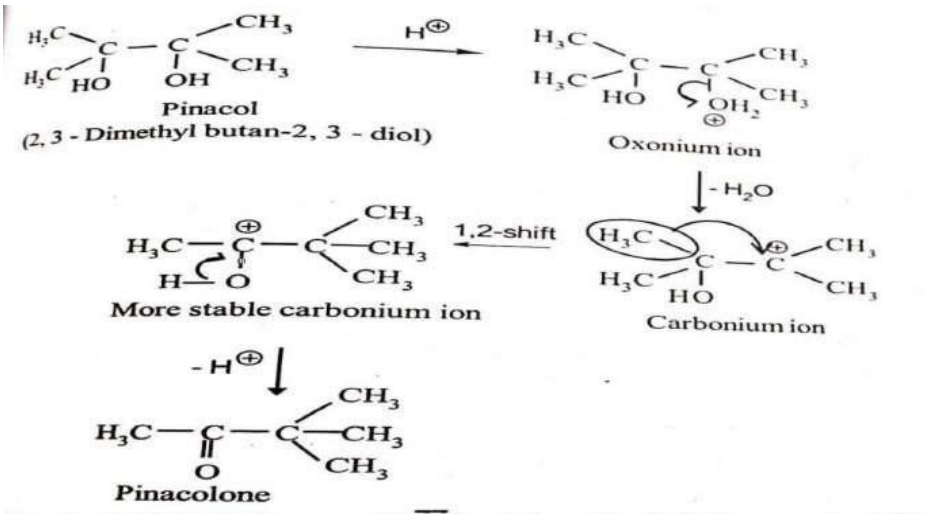
Pinacols are 1,2-diols of high order. when they are treated with high acids, undergoes dehydration and forms the corresponding Ketones known as pinacolone or pinacone. This is known as pinacols - pinacolone rearrangement.



Mechanism:

The mechanism involves with a four step with a simple 1,2 - shift.

- H+ ion combines with one of the -OH groups to form an oxonium.
- The oxonium ion eliminates a molecule of water and forms a carbonium ion.



- One of the methyl groups migrates with its octet to the carbonium ion leaving the other carbon atoms as more stable as carbonium ion.
- Finally from the carbonium ion a proton is released and electrons are redistributed to give the product.

The elimination of water molecule and the migration of methyl group takes place simultaneously. Thus the rearrangement is an intermolecular rearrangement. This Is further proved by kinetic studies and cross over experiments.

Uses of Pinacols - Pinacolone rearrangement:

- It is used to prepare the pinacolones which are highly branched Ketones. They cannot be prepared by other methods.
- It is used to convert cyclic Ketones into Pinacols which on rearrangement gives spiro-ketones.

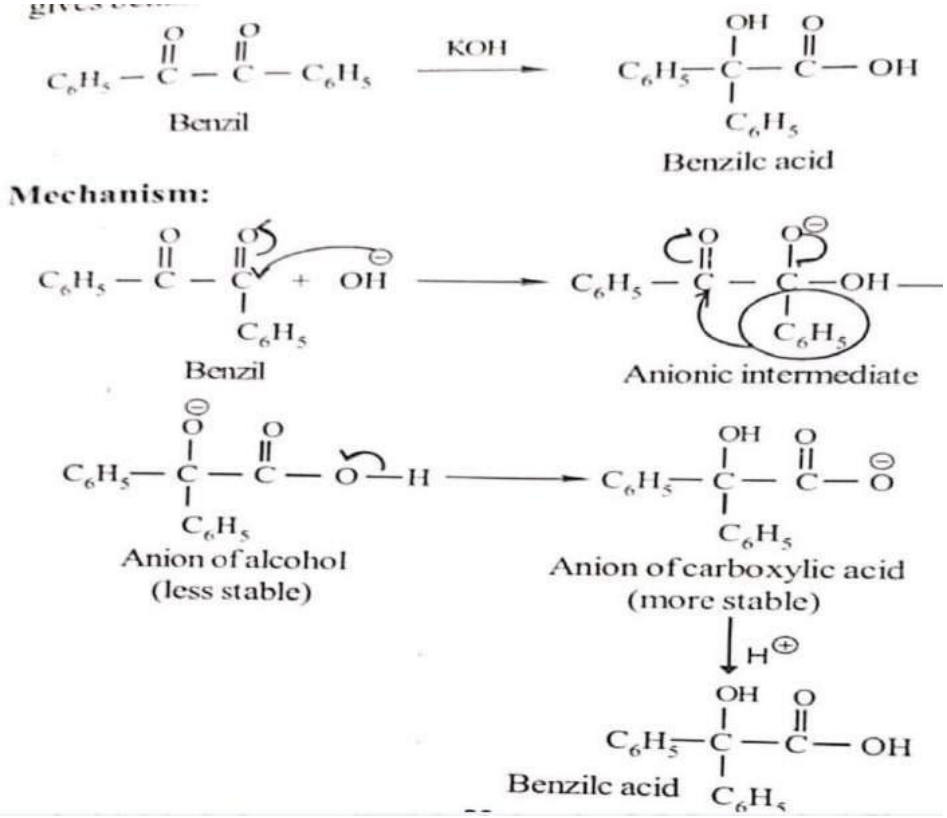
2. Benzil - Benzilic acid rearrangement:

Definition:

The base catalyzed conversion of 1,2-diketones into 2-hydroxy carboxylic acid is known as benzilic acid rearrangement.

EXAMPLE:

When benzil (aromatic 1,2 -diketone) is heated with KOH, it is converted to potassium benzilate. This upon hydrolysis gives benzilic acid.



This mechanism involves four steps:

- The addition of nucleophilic reagent to one of the carbonyl group gives the anionic intermediate.
- Phenyl group migrate with it's octet to the other carbonyl group. This is stabilized by releasing it's electron pair to oxygen. This intermediate is the anion of alcohol.
- This carboxylic acid group releases a proton to give more stable intermediate anions of the carboxylic acid.
- Finally the bezilate anion accepts a proton to give benzilic acid. This is an intermolecular rearrangement. It is proved by kinetic studies and cross over experiments.

Uses of benzilic acid rearrangement:

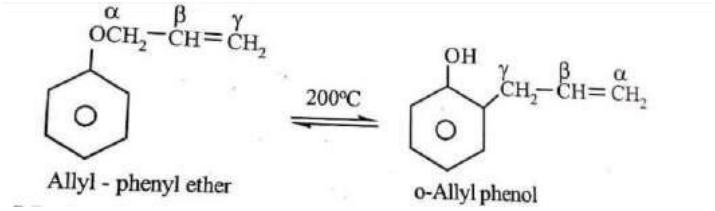
- Benzilic acid rearrangement is applied in the synthesis of citric acid.
- it is applied in the synthesis of hydroxy acid.
- Benzilic acid rearrangement is used for the route for the uses of non-steroids.
- This arrangement may be extended to the formation of esters by using alkoxides.

3. Claisen rearrangement:

Definition:

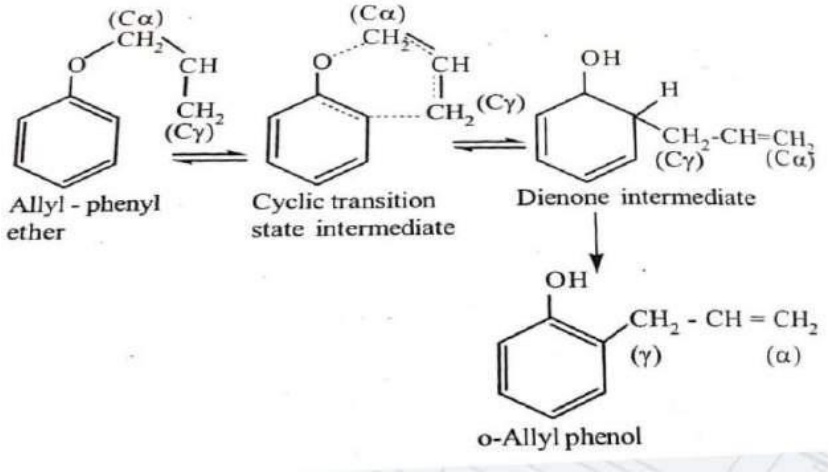
When allyl -aryl Ethers are heated to 200°C, ortho-allyl phenyls are obtained. This is known as Claisen rearrangement. It is thermal rearrangement.

Example: Allyl plenyl Ether's on Claisen rearrangement gives o-allyl phenol



Mechanism:

- Generally the allyl group migrates to the ortho position.
- If the two ortho positions are not free then the allyl group migrates to the para position. It is known as " para Claisen rearrangement "
- If both ortho and para position are not free then the migration does not occur.
- In the ortho migration the ends of the allyl group are interchanged. This is proved by using " tracer technique ".
- Using the above points an intermolecular mechanism is proposed. This involved the formation of a " cyclic transition state intermediate "
- From the dienone intermediate the final product is formed by the migration of ortho hydrogen. This is also proved using "tracer technique ".

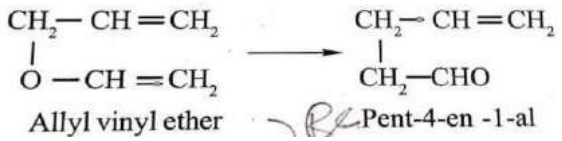


Claisen rearrangement is also known as "sigma tropic rearrangement ". This is because of the migration of "sigma bond". The oxygen -C sigma bond of the reactants migrate to the C-C position of the product.

This is an intermolecular rearrangement. It is proved by kinetic studies and cross over experiments

Uses of claisen rearrangement:

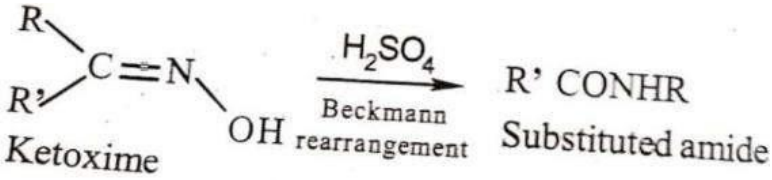
- Claisen rearrangement is used to synthesis o-euginol from guaiacol ally ether.
- Claisen rearrangement is used to explain the conversion of allyl vinyl ether into pent-4-en-1-al.



4. Beckmann rearrangement :

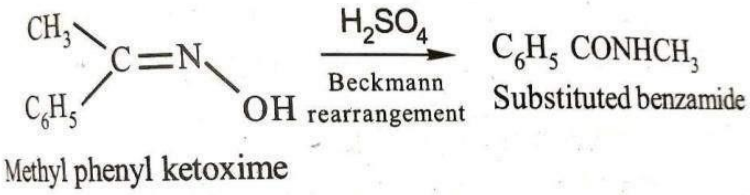
Definition:

When ketoximes are treated with H_2SO_4, P_2O_5, PCl_5they rearrange to give substituted amides. This is known as Beckmann rearrangement.



Example:

Methyl phenyl oxime on Beckmann rearrangement gives substituted benzamide.



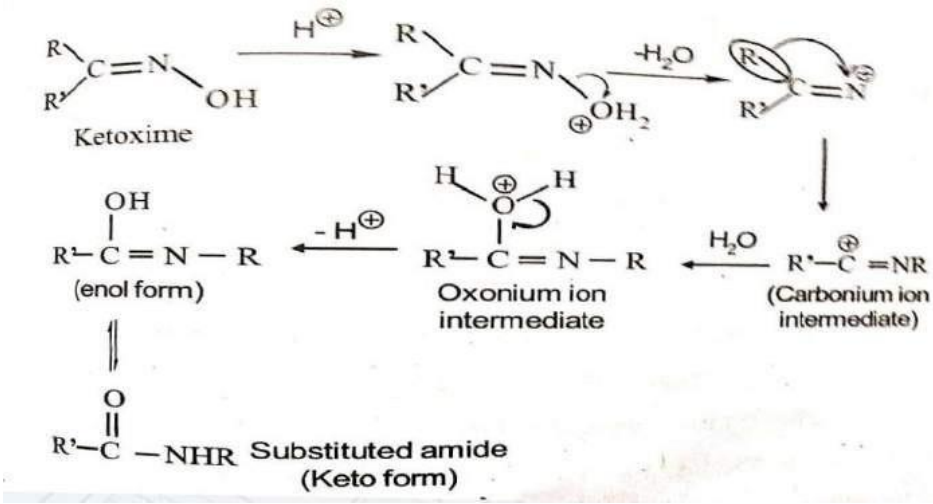
Mechanism:

This mechanism involves five steps.

- In acid medium the oxime undergoes protonation.
- The protonated intermediate undergoes dehydration.
- Now the R group migrates with its octet to the nitrogen atom and thus

makes the carbon atom as C^+ ion.

- The carbonium ion intermediate takes a molecule of water to form the oxonium ion intermediate.
- The oxonium ion release a proton to form the enol compound.
- Finally the enol form undergoes tautomerism to give the keto form. The substituted amide.



It is a stereospecific rearrangement involving anti group migration. Therefore it is known as" anti rearrangement. "

This is an intermolecular rearrangement. It is proved by kinetic studies and cross over experiments.

Uses of Beckmann rearrangement:

- This rearrangement is applied to assign configuration for ketoximes.
- It is also applied in the synthesis of textile polymer perlon.
- It is applied in the synthesis of is oquinoline.

5. Hofmann rearrangement :

Definition:

Transformation of an amide into a primary anime by the action of sodium hypobromite is known as Hofmann rearrangement.

Example:

$CH_3CONH_2 \xrightarrow{NaOH/Br_2} CH_3NH_2$

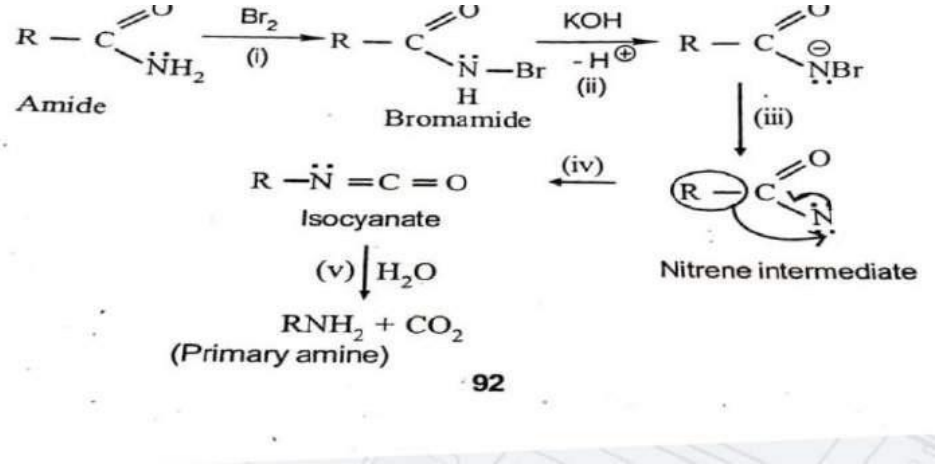
Acetamide — Methylamine

Mechanism:

The mechanism involves five steps.

- Amide reacts with Br_2/NaOH to give bromamide intermediate.
- Presence of two electron with drawing groups make the bromamide to release H^+ and and forms and intermediate.
- This intermediate releases $Br^{(-)}$ and forms a "nitrene intermediate. "
- Simultaneously the R group migrates with its octet to N atom and forms isocyanate.
- The isocyanine formed on hydrolysis gives primary amine.

Thus is an intermolecular rearrangement. It is proved by kinetic studies and cross over experiments.



Uses of Hofmann rearrangement:

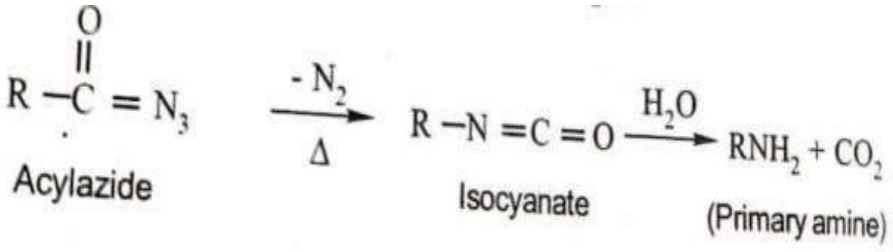
- It is applied in the synthesis of B-amimopyridine.
- It is used to synthesis amino acids like B-alanine.
- It is used to convert α,β- unsaturated acid into aldehydes.
- It is used to synthesis primary amines.

6. Curtis rearrangement :

Definition:

The pyrolysis of acylazides into isocyanates and their hydrolysis into primary amine Is known as curtius rearrangement. It is also a thermal rearrangement.

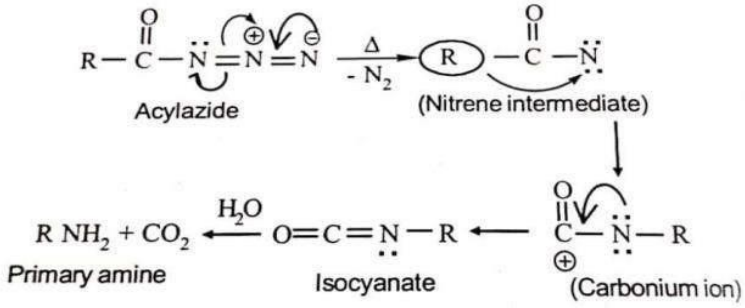
Example:



Mechanism:

This mechanism is catalysed by Lewis acid, protic acid etc.

- This mechanism involves the formation of "nitrene" intermediate
- "R" group migrates with its octet to form hydrogen. This produce a carbonium ion.
- Isocyanate is formed from carbonium ion by redistribution of electrons.
- The isocyanate on hydrolysis gives primary amine.



This is an intermolecular rearrangement. It is proved by kinetic studies and cross over experiments.

Uses of curtius rearrangement:

- Used to prepare primary amine.
- Used to prepare a-amino acids.
- Used in the preparation of urethanes.
- Used in the preparation of aldehydes.

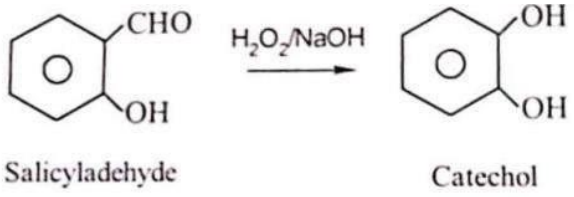
7. Dakin reaction :

Definition:

Replacement of the aldehydes or acetyl group in phenolic aldehydes or Ketones by a hydroxyl group on reaction with alkaline hydrogen peroxide is known as dakin reaction.

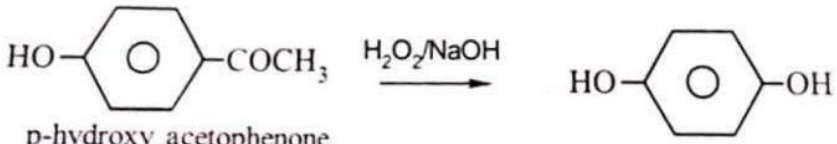
Example:

Salicyl aldehyde on Dakin reaction gives catechol.



Salicyladehyde Catechol

ii) P-hydroxy acetophenone on Dakin reaction gives hydroquinon

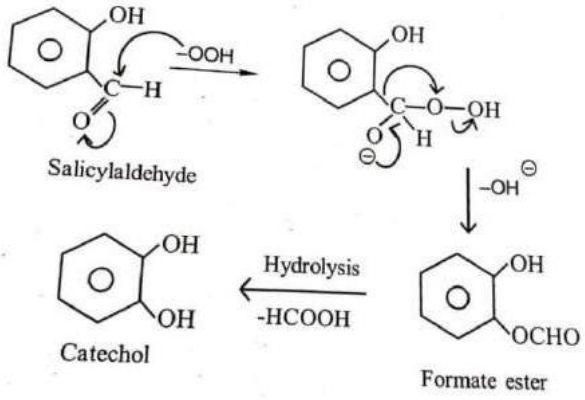


p-hydroxy acetophenone Hydroquinone

Mechanism:

The mechanism of this rearrangement is same to Baeyer-Villiger oxidation.

- Carbonyl carbon is attacked by the hydroperoxide anion.
- Migration of aryl group along with the elimination of hydroxide ion gives formate Ester.
- Fomate Ester on alkaline hydrolysis gives catechol.



Uses of Dakin rearrangement:

Dakin reaction has been used to synthesis many polyhydric phenols from naturally occurring hydroxy aldehydes.

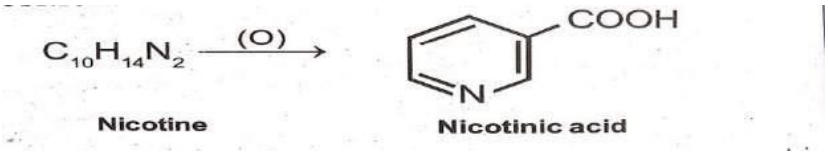
UNIT - IV
TERPENOIDS AND ALKALOIDS

NICOTINE:

a) Sources: Tobacco leaves

b) Structural elucidation of nicotine:

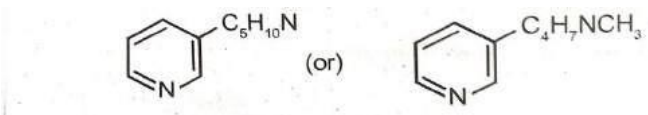
- The molecular formula of nicotine is $C_{10}H_{14}N_2$.This is proved by analytical data and molecular weight determination.
- With HCl it forms the crystalline salt, nicotine dihydrochloride. This proves that nicotine is a diacid base
- On treatment with CH_3I, it forms dimethyliodide, but does not form an acetyl or benzoyl derivative. This suggests that nicotine is a di-tertiary base.
- Herzig-meyer determination prove that nicotine contains one ($-NCH_3$) group.
- Nicotine on oxidation with $KMnO_4$ or chromic acid gives nicotine acid(piridine-3-carboxylic acid).This proves that nicotine is a pyridine derivative containing a side chain at 3-position.



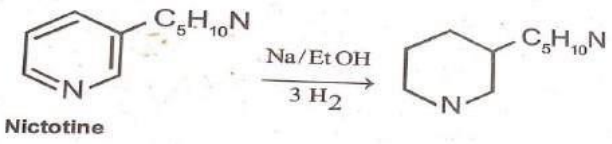
1. The difference between the molecular formulae of nicotine and 3-substituted pyridine gives the molecular formula of the side chain

$$\underset{\text{Nicotine}}{C_{10}H_{14}N_2} - \underset{\text{3-substituted pyridine}}{C_5H_4N} = C_5H_{10}N$$

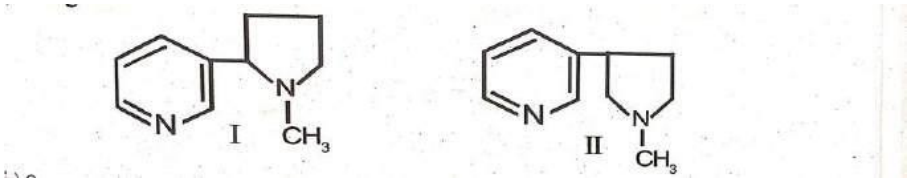
Thus nicotine can be written as



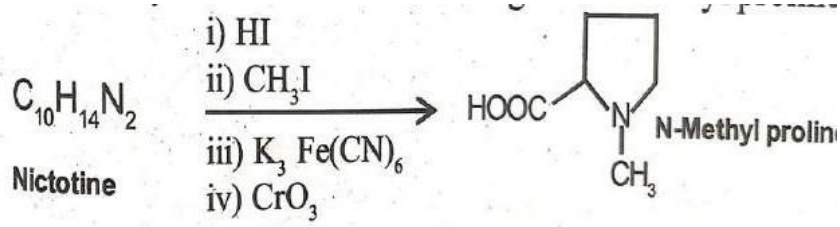
2. With sodium-ethanol mixture, nicotine is completely reduced to piperidine derivative with no change in side chain. This proves that the side chain should be saturated.



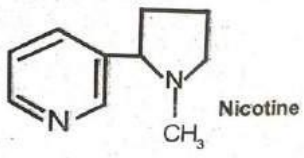
3. When nicotine-zinc chloride complex is distilled with lime, the products are pyridine, pyrrole and methylamine. This suggests that the side chain ($C_5H_{10}N$) should be a pyrrole derivative. Therefore nicotine may be assigned either of the two following structures.



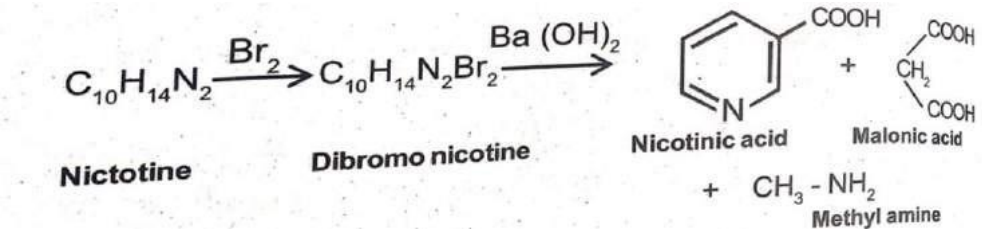
4. One reaction with CH_3I, nicotine hydroiodide gives nicotine isomethiodide. This upon oxidation with potassium ferricyanide, followed by dichromate oxidation gives N-methyl proline.



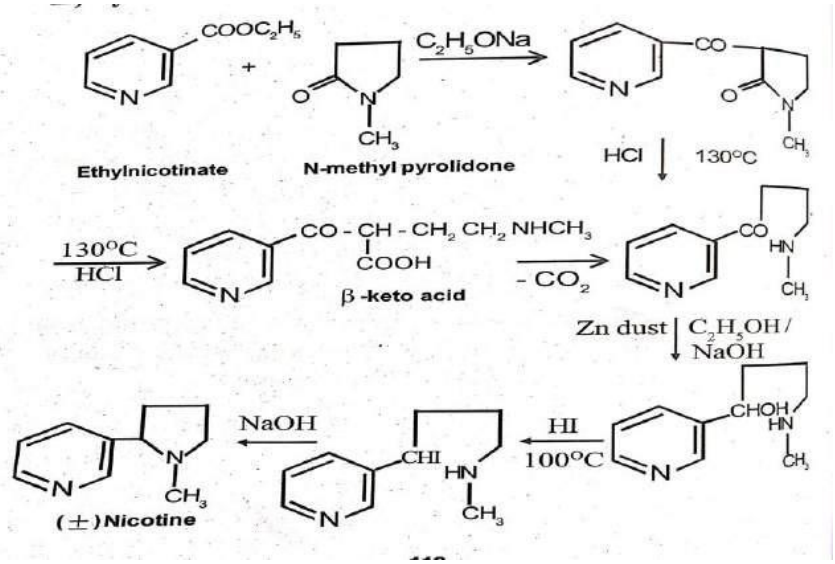
This proves that the a-position of pyrrolidine unit is attached to position 3 of the pyridine nucleus. This confirms the structure I. Thus the structure of nicotine can be given as



5. The above structure of nicotine is also proved by the following reaction. Nicotine when treated with bromine, forms dibromonicotine. This on heating with barium hydroxide, breaks down to give nicotine acid, malonic `acid and methylamine.



6. Synthesis of nicotine:



Finally the above structure of nicotine is confirmed by its synthesis by spath etal. This synthesis involves crossed claisen condensation of ethyl nicotinate withN-methyl-2-pyrolidone.

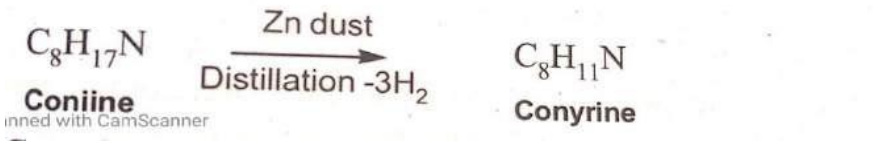
Coniine:

a) source: Hemlock seeds

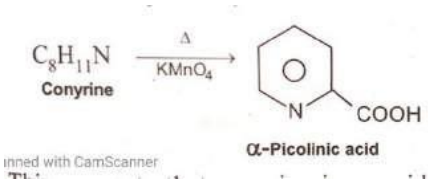
b) Structural elucidation of coniine:

1. The molecular formula of coniine is C8H17N.This is proved by analytical data and molecular weight determination.

2. Coniine on distillation with zinc dust gives conyrine. This compound contains six hydrogen atoms less than coniine.



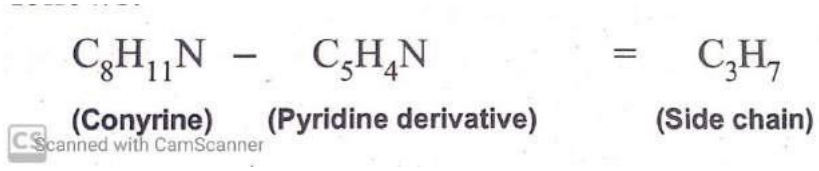
3. Conyrine on oxidation with KMnO4 gives a-picolinic acid (pyridine-2-carboxylic acid).



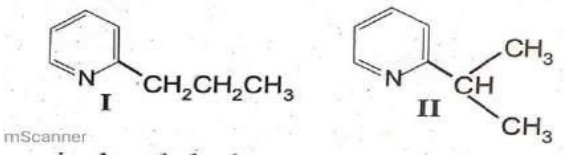
This suggests that conyrine is a pyridine derivative containing a side chain at position 2 only.

1. Nature of the side chain:

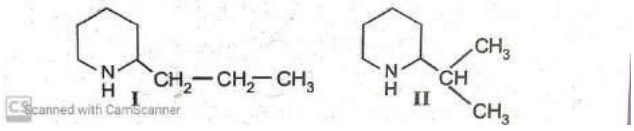
The molecular formula of the side chain can be obtained as follows.



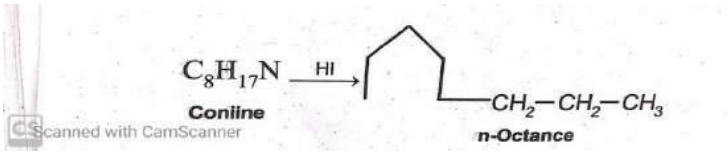
2. Therefore conyrine may be represented by the following two structures.



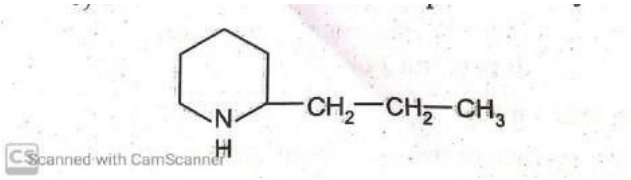
3. Since conyrine has six hydrogen atoms less than coniine,the latter is probably piperidine derivative and may be represented by the following two structures.



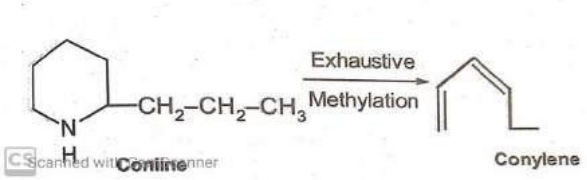
4. When heated with HI at 300° under pressure, coniine forms n-octane and not isooctane. This proves that the side chain of coniine is only n-propyl(I) and not isopropyle (II).



5. Therefore coniine can be represented by structure (I).

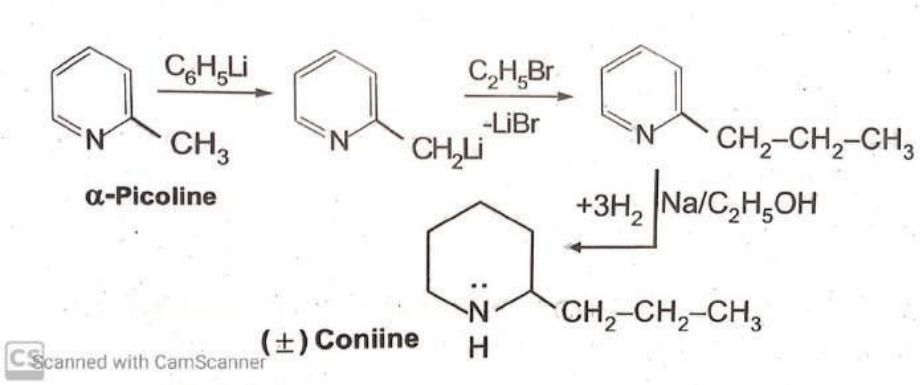


6. The above structure of coniine is further proved by the formation of conylene(C_8H_{14}) by Hofmann exhaustive methylation.



7. The structure of coniine is further proved by the following synthesis from a-picoline.

Bergmann synthesis of coniine:



TERPENES AND TERPENOIDS

Classification:

Terpenes are classified on the basis of number of C_5(isoprene)units present in them.

Class	No. of isoprene units	Example
a) Hemiterpenes	one isoprene unit (C_5)	-
b) Monoterpenes	two isoprene units (C_{10})	Citral, limonene
c) Sesquiterpenes	three isoprene units (C_{15})	Farnesol, zinziberene
d) Diterpenes	four isoprene units (C_{20})	Phytol
e) Triterpenes	six isoprene units (C_{30})	Squalene
f) Polyterpenes	several isoprene units $(C_5)_n$	Rubber

Terpenes are further subdivided into acyclic or cyclic terpenes. Acyclic terpenes possess open chain structure (myrcene) and cyclic terpenes possess ring structure (limonene).Cyclic terpenes are further classified into monocyclic (limonene) bicyclic (a-pinene) or tricyclic (abietic acid) according to the number of rings present on them.

Citral:

Occurrence:

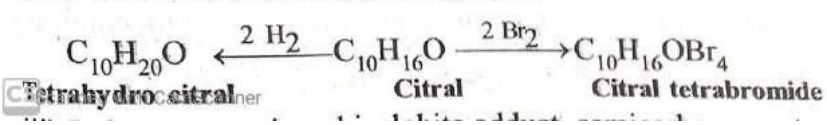
It occurs in the oils of lemon, oranges and citronella etc.

Structural elucidation of citral:

a. The molecular formula of citral given by analytical data and molecular weight determination is C10H16O.

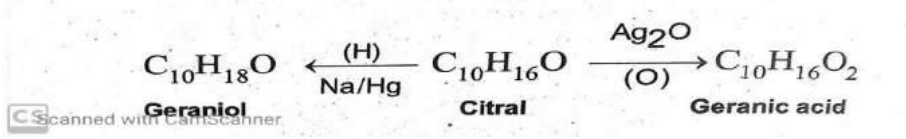
b. It forms tetrahydro and tetrabroma derivatives with hydrogen and bromine respectively.

Therefore, it contains two double bonds.

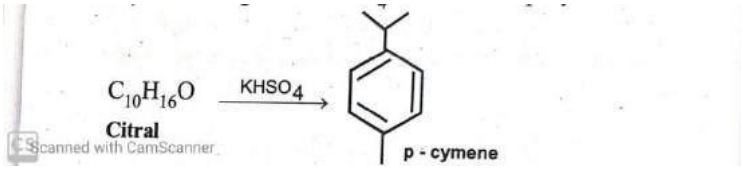


It forms an oxime, bisulphite adduct, semicarbazone etc. On oxidation with moist silver oxide it forms geranic acid containing same number of carbon atom. On reduction it gives the primary alcohol, geraniol. All these reactions

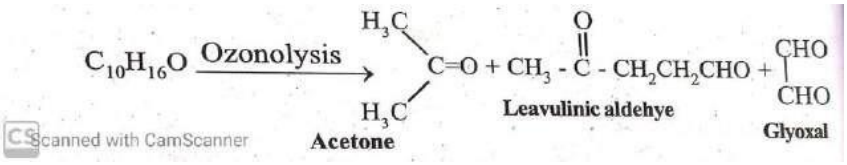
confirm that citral contains an aldehyde group.



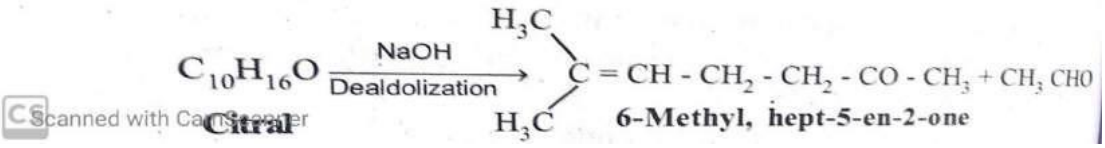
On heating with KHSO4, citral forms p-cymene.



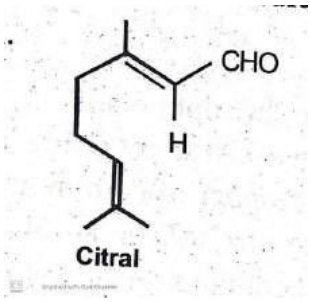
Citral on ozonolysis gives acetone,laevulinic aldehyde and glyoxal



When boiled with con.aqueous alkali, citral undergoes dealdolization and gives acetaldehyde and 6-methyl,hept-5-en-2-one.

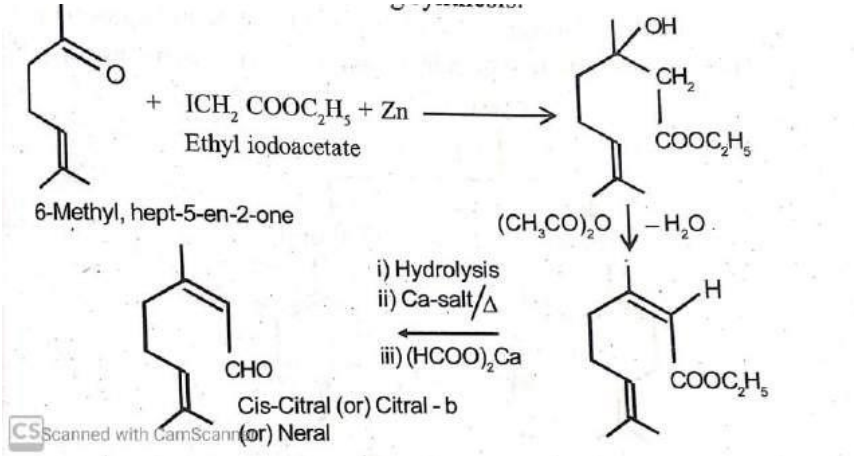


Ozonolysis and dealdolization studies suggest the following structure for citral.



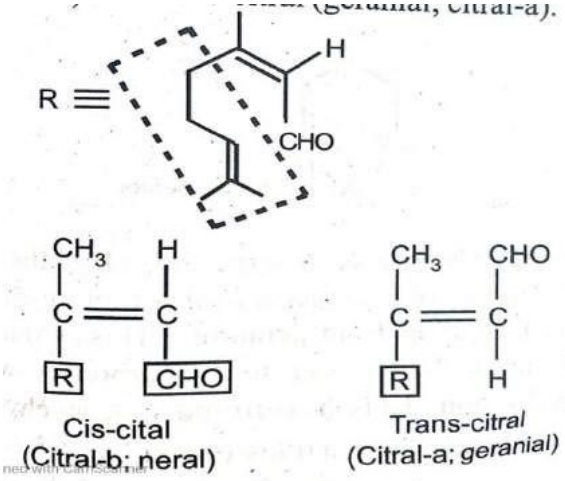
Synthesis of citral:

Finally the above structure of citral is confirmed by the following synthesis.



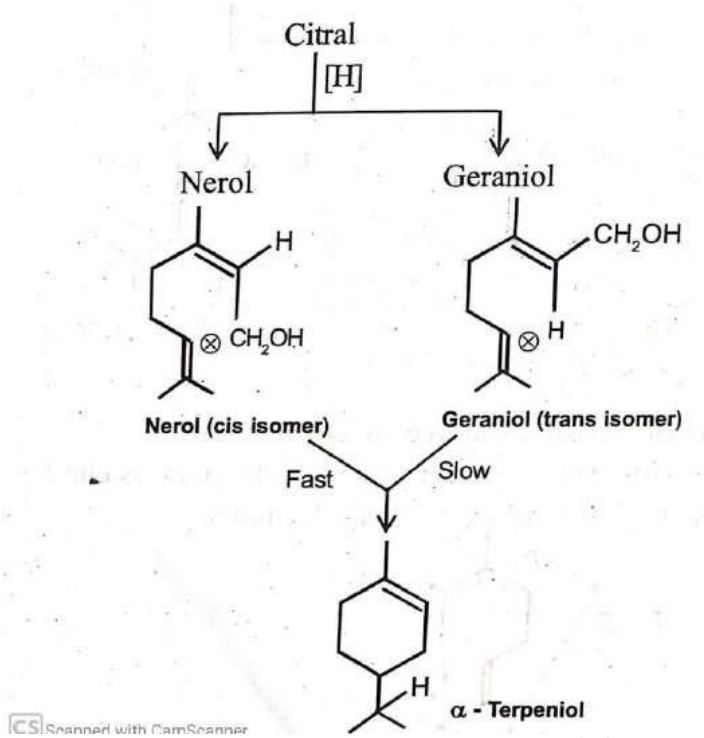
Cis-Trans isomerism exhibited by citral:

Citral exists in two geometrical isomeric forms as cis-citral (neral; citral-b) and trans-citral (geranial; citral-a).



Evidence to prove that neral is a cis isomer and geranial is a trans isomer:

Usually citral contains a mixture of cis-citral and trans-citral. Therefore this mixture on reduction gives two isomeric alcohols.



On cyclization both give a-terpeniol. But the rate of formation of a-terpeniol from nerol is nine times greater than the rate of its formation from geraniol.This is due to the proximity of the alcoholic group to the carbon x which is involved in cyclization.Thus the corresponding aldehyde neral is a cis-isomer and geranial is a trans-isomer.

Menthol:

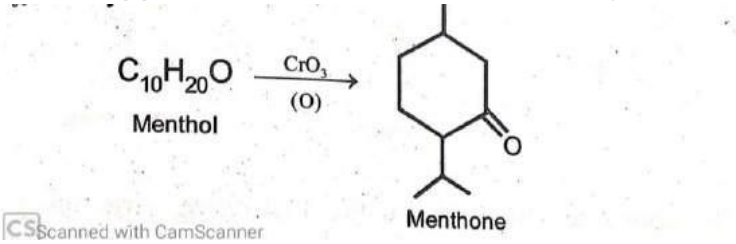
Occurrence:

It occurs in peppermint oil.

Structural elucidation of menthol:

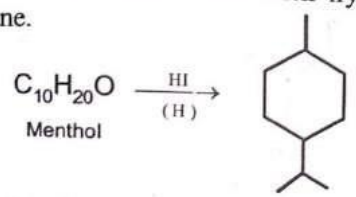
1. Molecular formula of menthol given by analytical data and molecular weight determination is $C_{10}H_{20}O$.

2. Menthol an oxidation with chromic acid gives menthone which is a ketone.This reaction suggests that menthol is a secondary alcohol

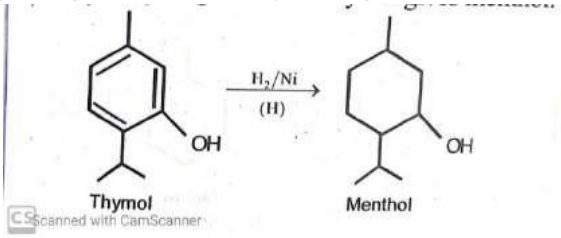


Menthol of reduction with hydroiodic acid gives p-menthane.

iii) Menthol on reducation with hydroiodic acid gives p-menthane.

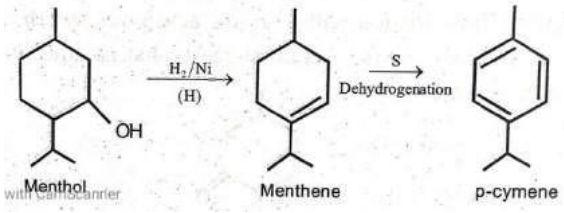


3. Catalytic hydrogenation of thymol gives menthol

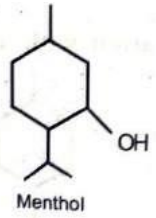


This reaction suggests that the position of-OH group in menthol should be C3

4. Dehydration of menthol with $KHSO_4$ gives menthene which on dehydrogenation with sulphur gives p-cymene

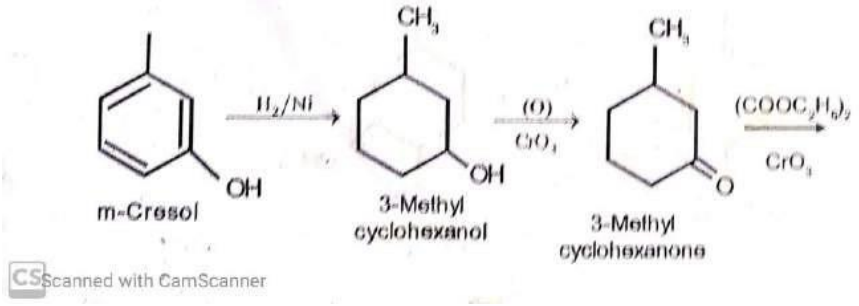


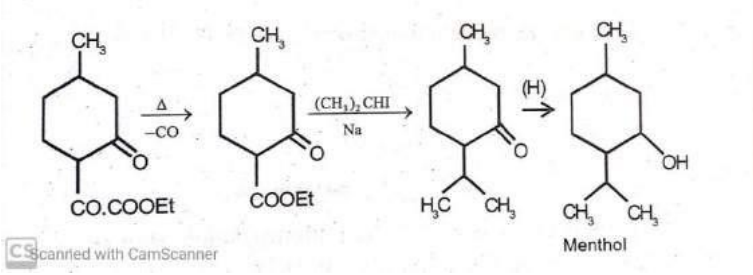
The above reaction prove the following structure of menthol



Synthesis of menthol:

The above structure of menthol is further proved by the following synthesis.





Limonene (Dipentene)

Limonene is an optically active compound. The racemic form of limonene(+or-) is known as dipentene.

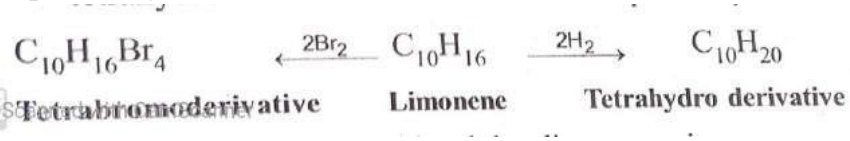
Occurrence:

The limonene form is available in lemon, orange, peppermint oil etc. The dipentene form is available in turpentine oil.

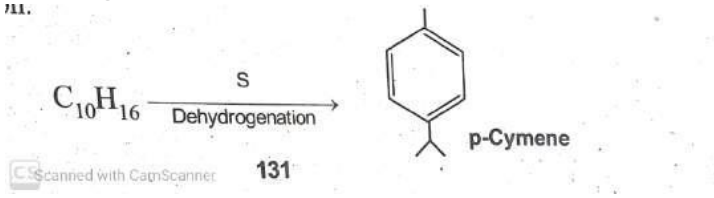
Structural elucidation of limonene:

1. The molecular formula of limonene is C10H16.

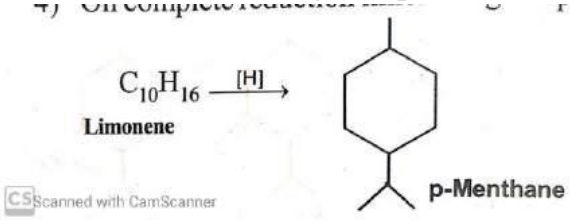
2. The presence of double bonds in limonene is proved by its addition reaction with hydrogen and bromine to give tetrahydro and tetrabromo derivatives respectively.



3. On dehydrogenation with sulphur limonene give p-cymene.This confirms that limonene is having a similar carbon skeleton.

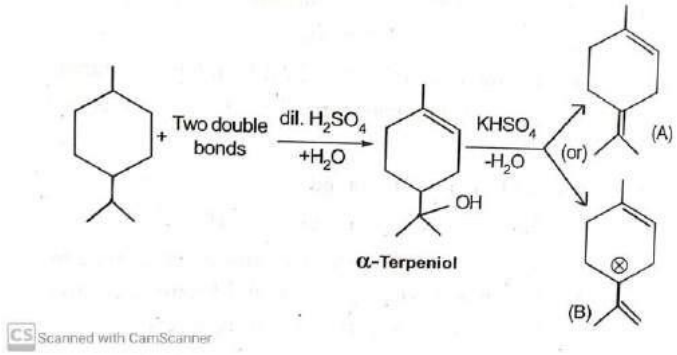


4. On complete reduction limonene gives p-menthane.

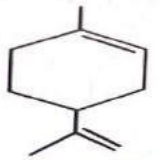


Thus limonene is p-menthane with two double bonds.

5. Limonene on hydration with dil.H2SO4 gives a-terpeniol which on dehydration gives back the limonene.



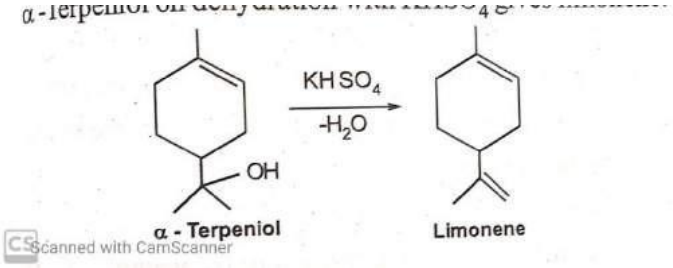
6. Thus the structure of limonene may be either (A) or(B). Limonene is optically active.This is possible only with structure (B).This structure contains the asymmetric carbon atom(x).Thus the structure of limonene is



7. Finally the above structure of limonene is proved by the following syntheses.

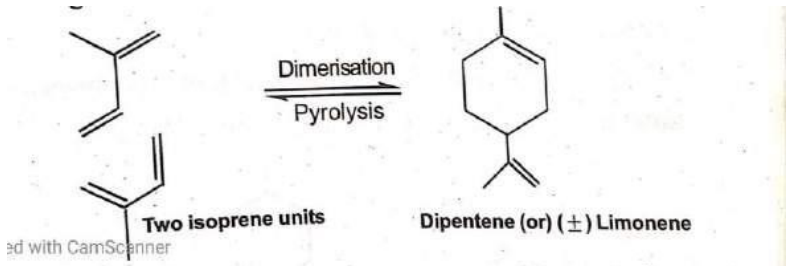
Dehydration of a - terpeniol with KHSO4:

A - Terpeniol on dehydration with KHSO4 gives limonene.



Dimerization:

When isoprene molecules are heated in a sealed tube,they undergo dimerization to give dipentene.



Camphor:

a) Source:

It is a main constituent of camphor oil obtained from the wood and leaves of the camphor tree (Cinnamomum camphora).

b) Structural elucidation of Camphor:

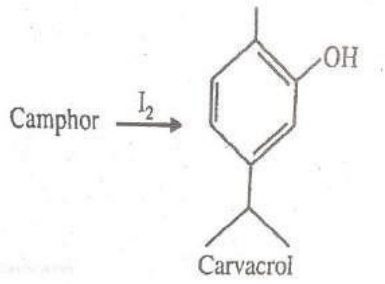
Molecular formula:
From analytical data and molecular weight determination,it follows that the molecular formula of camphor is $C_{10}H_{16}O$.

Saturated characteristics:
Camphor does not add with bromine.However,it forms monosubstitution products like mono-bromo camphor etc.The formation of these products reveals that camphor is a saturated compound and does not contain any double bond.This is further supported by the facts that (1) it does not react with 1%alk.$KMnO_4$ and (2) molecular refraction also favours this.

Presence of a keto group:
The nature of oxygen atom is found to be cyclic ketonic on the basis of following facts.

$$\underset{\text{Camphor}}{C_{10}H_{16}O} + H_2NOH \longrightarrow \underset{\text{Camphor oxime}}{C_{10}H_{16}=N-OH}$$

- It forms an oxime with hydroxylamine
- It forms semicarbazone with semicarbazone.
- It forms phenylhydrazone with phenylhydrazone.
- Camphor when oxidised with nitric acid, yields a dicarboxylic acid called camphoric acid without loss of carbon atoms. Further, camphor when reduced with sodium amalgam, yields a secondary alcohol called borneol. Hence, camphor must be a cyclic ketone.
- When camphor is distilled with iodine, it yields carvacrol.



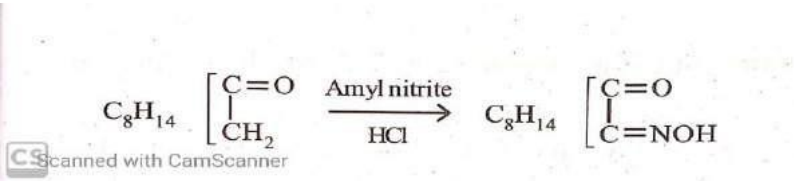
The presence of phenolic group in carvacrol reveals the presence of ketonic group in camphor.

Bicyclic system:

The molecular formula of saturated parent hydrocarbon of camphor is $C_{10}H_{18}$ which corresponds to the general formula C_nH_{2n-2} of bicyclic compounds and, therefore, camphor is a bicyclic compound.

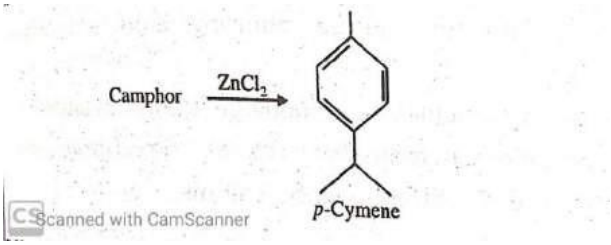
Presence of -CH_2CO group

When camphor is treated with amyl nitrite and hydrochloric acid,it yields an iso-notroso(oximino) camphor in which two hydrogen atoms have been replaced by =NOH group.This reaction reveals that the >C=O group is directly attached to a -CH_2 group



Presence of a six membered ring:

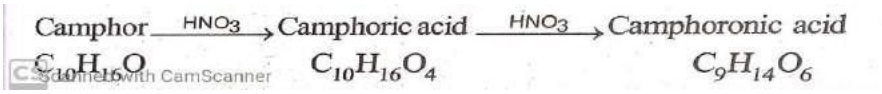
When camphor is distilled with zinc chloride or phosphorus pentoxide,it yields p-cymene.The formation of the latter product reveals the presence of six membered ring, methyl and gem-dimeyhyl groups in camphor.



Nature of the carbon-ftame in camphor:

When camphor is oxidised with nitric acid,it yields a crystalline dibasic

acid, camphoric acid $C_{10}H_{16}O_4$.As camphoric acid possesses the same number of carbon atoms as camphor,it means that the keto group must be present in one of the rings in camphor. Thus during the conversion of camphor into camphoric acid,the opening of ring containing the keto group occurs and therefore, camphoric acid must be a monocyclic compound.
When camphoric acid is further oxidised with nitric acid, camphoronic acid is obtained.

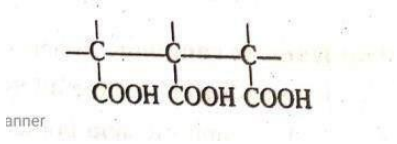


In order to elucidate the structure of camphor,the structure of camphoric acid and camphoronic acid should be known.

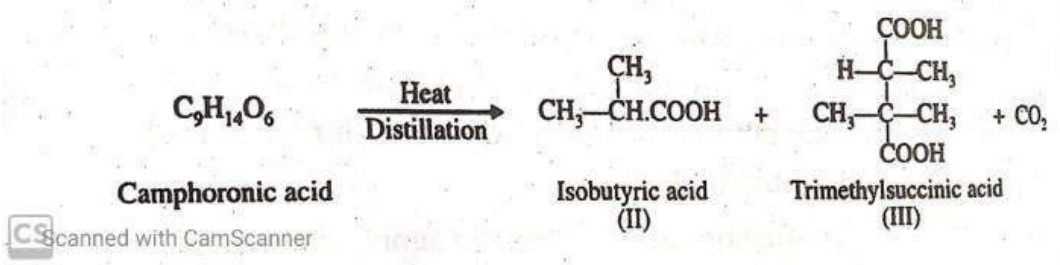
Structure of camphoronic acid:

This can be elucidated as follows:

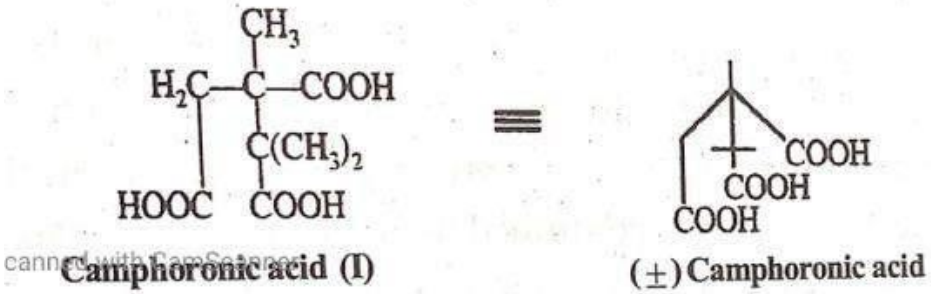
- The molecular formula of camphoronic acid is $C_9H_{14}O_6$.
- As a camphoronic acid has been shown to be a saturated tricarboxylic acid,it's parent hydrocarbon will, therefore, C_6H_{14} which corresponds to the general formula (CnH2n+2)for acyclic compound, indicating that camphoronic acid is an acyclic compound.
- As camphoronic acid does not undergo decarboxylation under ordinary conditions,it mean that it's three carboxyl groups should be attached to three different carbon atoms.



a) When camphoronic acid is distilled at atmospheric pressure,it yields isobutyric acid (II) trimethylsuccinic acid (III) and carbon dioxide as the major products.

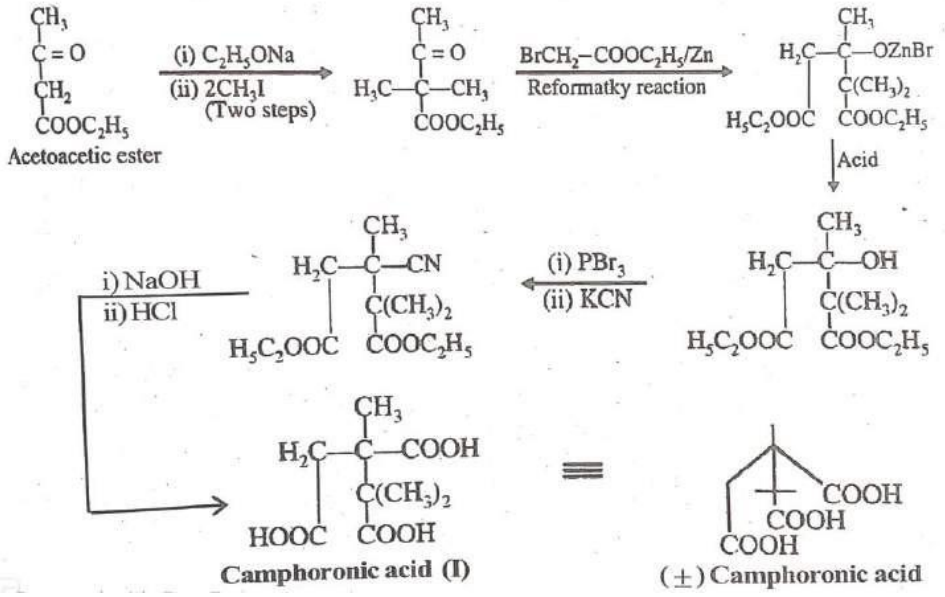


In order to explain the formation of these products,Brest suggested that camphoronic acid is a, a, B-tri carballylic acid(I).



Synthesis of Camphoronic acid:

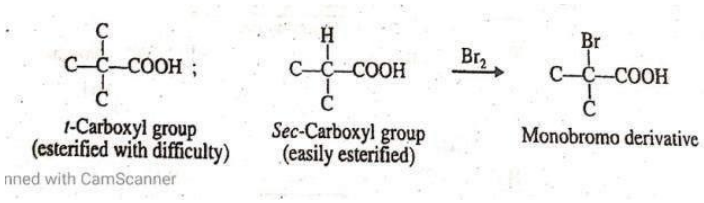
The structure (I)for camphoric acid has been confirmed by its following synthesis.



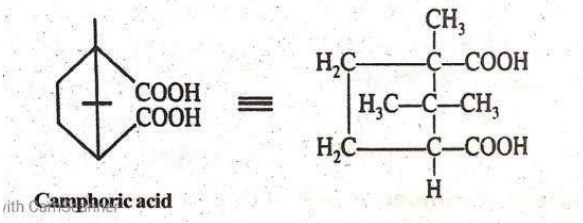
Structure of camphoric acid:

It is elucidated as follows:

- The molecular formula of camphoric acid is $C_{10}H_{16}O_4$.
- By usual tests, camphoric acid has been shown to be a saturated dicarboxylic acid.
- Camphor is bicyclic. During the oxidation of camphor into camphoric acid,the ring containing the keto group gets opened and hence camphoric acid should be monocyclic.
- As camphoric acid is able to form a monoester readyly but it forms diester with difficulty, this shows that the two carboxyl groups are not similar,i.e.,one is primary and secondary and the other is tertiary. Thid is confirmed by the fact that camphoric anhydride forms only one monobromo derivative with phosphorus/bromine.The formation of thismonobromo derivative is only possible if one of the carboxyl groups is secondary,ie.the carbon atom of one carboxyl groups must be 1C

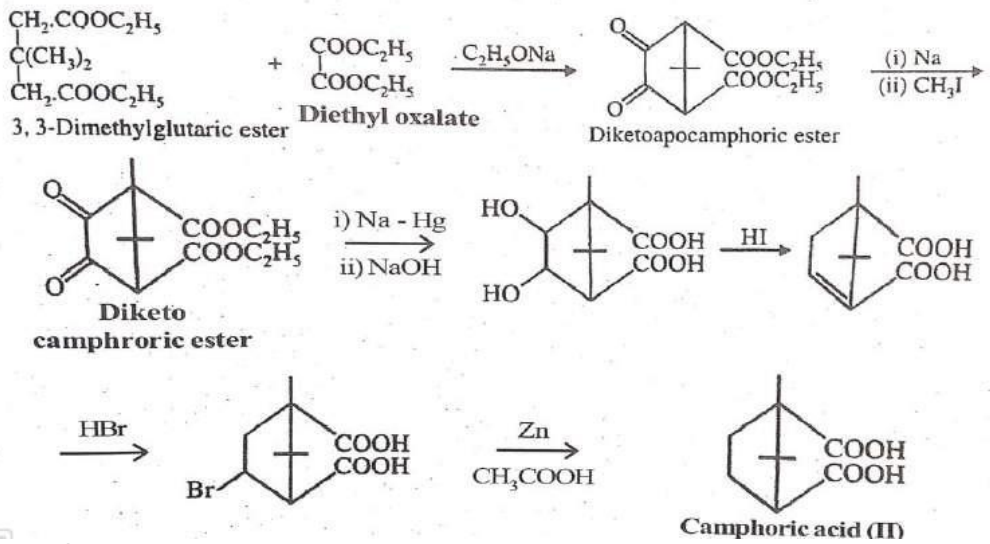


a) on the basis of the above facts the structure of camphoric acid may be given as follows.



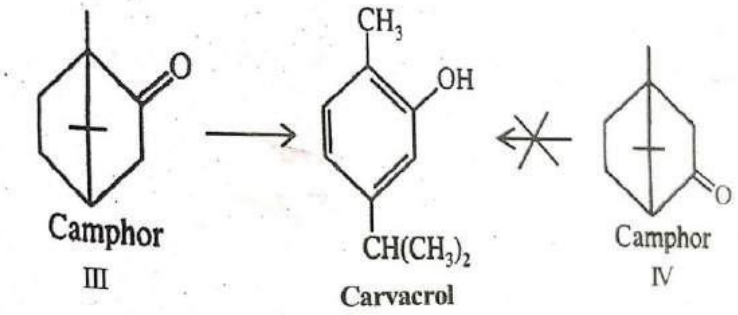
Synthesis of(+ or -) - camphoric acid:

This involves the conversion of 3,3-dimethyl-glutaric ester into camphoric acid as follows:



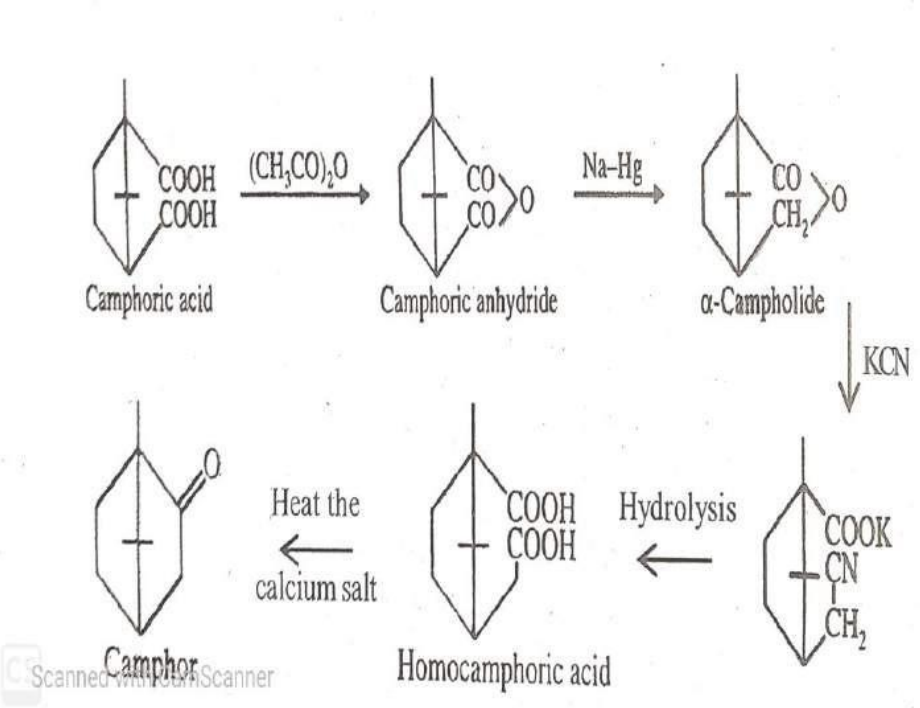
Structure of camphor:

On the basis of the foregoing discussion the structure of camphor may be given as either III or IV. Camphor gives carvacrol on distillation with iodine. This is possible only from structure III and not form structure IV.



Synthesis of camphor:

The above structure (III) of camphor is proved by the following synthesis.



UNIT –V
ORGANIC SPECTROSCOPY

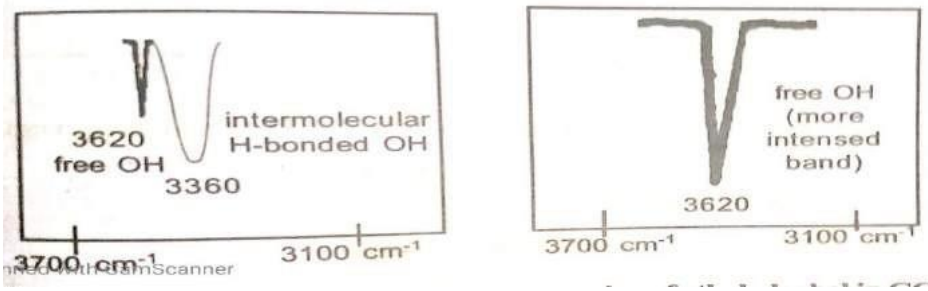
APPLICATION OF IR SPECTROSCOPY:

STUDY OF HYDROGEN BONDING (inter and intra molecular hydrogen bonding)

The free hydroxyl group of alcohols and phenols in the vapour phase appears as a sharp band at 3650-3580cm-1. But for the hydrogen bonded hydroxyl group lowers the absorption frequency and appears as a broad band at 3500-2600cm$^{-1.}$

IR spectra may be used to distinguish inter and intramolecular hydrogen bonding by studying the effect of dilution. Intermolecular hydrogen bonds are concentration dependent and it increases as the concentration of the solution increases. This appears as an additional broad band at 3500-3200 cm-1 along with Sharp free OH band at 3650 - 3580 cm^{-1}.

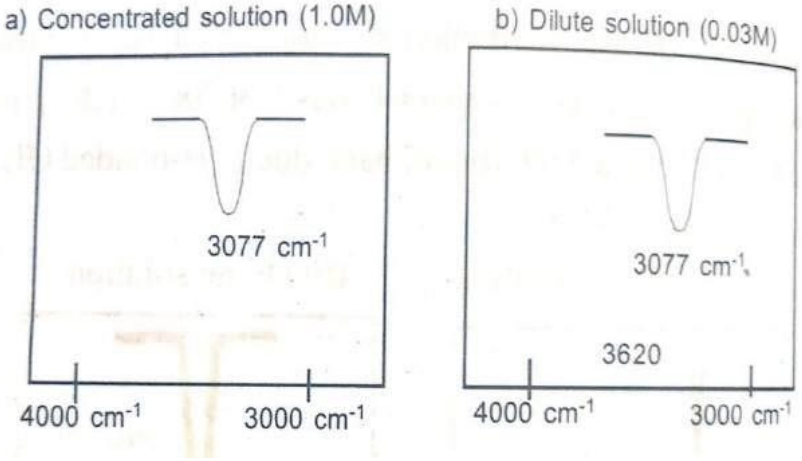
Example: The IR sepctra of ethyl alcohol in Ccl4 (concentrated solution) gives two O-H absorption bands at 3620cm^{-1} (sharp band due to free OH) and 3360(broad band due to H-bonded OH)



On dilution, the intermolecular hydrogen bonds are broken. Hence the broad band due to H- bonded OH at 3360cm^{-1} decreases and finally disappears. Hence for dilute solution, only one more intense absorption band due to free OH is appeared

Intermolecular hydrogen bonds are independent of concentration. On dilution, the absorption band remains unaffected

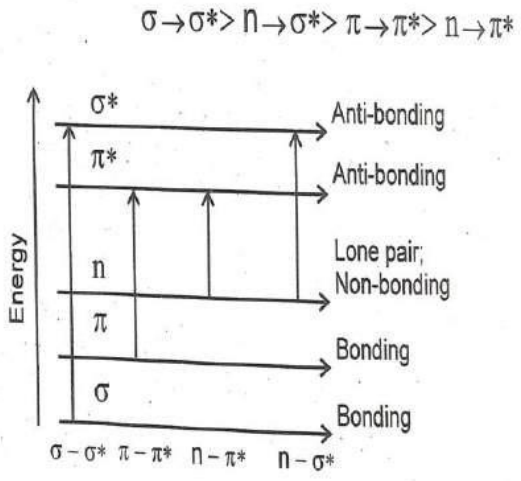
Example: The IR spectra of concentrated solution of methyl salicylate gives an absorption band at 3077cm^{-1}. This band is due to intramolecular H-bonded OH. This appears as a shallow broad band. On dilution, this absorption band remains unaffected.



TYPE OF ELECTRONIC EXCITATION

The electrons of the single bonds are called the sigma elactron and the electron of the double or triple bonds are called the π electrons. In addition to sigma, π electrons, unpaired electron can exist in molecules containing atom such as oxygen, nitrogen, etc.,

When a molecules is excited by a radiation energy, the electron can be excited from a bonding or non-bonding orbital to a higher -energy antibonding orbitals which are vacant in the ground state.



Types of transitions and the energy of n,π, σ electrons

- **σ – σ *transition**

The transition of an electron occurs from a binding sigma orbital of a molecule to the higher energy antibonding sigma orbital is known as σ-σ* transition. These transition occurs at the highest excitation energy than the others. These transition are mainly observed in saturated hydrocarbons and their characteristics bands appear in the "vacuum UV region"

Examples:
Methane λmax =122nm
Ethane λmax =135nm

- **π-π* transition**

The transition of an electron occurs from πbonding orbital to π* orbital is known as π-π* transition. These transition are observed in unsaturated compound such as alkenes, alkynes, carbonyl compounds, etc., Their band appears in the near UV region.

Examples:
1,3-butadiene λmax =217 nm
Acetophenoneλmax =240 nm

- **n-σ* transition**

The transition of an electron occurs from the non bonding orbital of the ground state to the antibonding sigma orbital is known as n-σ*transition. These transition are observed in saturated halides, amines, alcohols, etc., Their bands appear in the vacuum region

Examples
Methyl alcohol λmax =174nm
Methyl chloride λmax =169 nm

- **n-π* transition.**

The transition of an electron occurs from the nonbonding orbital of the ground state to the antibonding π*orbital. This transition occurs at the lowest energy then the others. These transition are mainly observed in Saturated aliphatic ketones and aldehydes. Their bands appears in the near UV region.

Examples:
Acetone 270nm

Acetaldehyde 293nm

CHEMICAL SHIFT (position of NMR signals)

The separation in the positions of the spectral signals of H atom in different chemical environment from that of a standard reference is called chemical shift. Chemical shift is usually reported as,

$$\delta = \frac{H_S - H_{ref}}{H_0} \times 10^6 \text{ and}$$

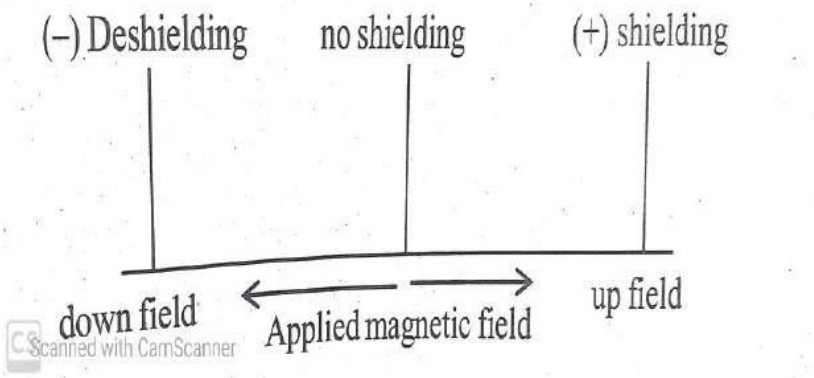
$$\delta = \frac{\nu_S - \nu_{ref}}{\nu_0} \times 10^6$$

Where Hs and Vs are the resonance field and frequency for the sample Href and Vref are the resonance field and frequency for the reference and Ho and Vo are the applied field and it's frequency.

Generally the reference compound used is tetrametylsilane (TMS). There are two scale used for measuring chemical shifts namely delta scale and τ scale and they are related by the expression. The chemical shift for the TMS proton is taken to be zero in that delta (δ) scale.

When a molecules is placed in a magnetic field its electron are caused to circulate and in circulating, they generate a secondary magnetic field or induced magnetic field. This induced magnetic field produced by the applied magnetic field.

If the induced field opposes the applied magnetic field, the proto is said to be shielded. If the induced field reinforced the applied magnetic field the proton is said to be deshielded. Compared with naked proton, as shielded proton requires a higher applied field strength and a deshielded proton requires a lower applied field strength. This shielding and deshielding of proton by the electrons causes chemical shift.



Due to chemical shift, different type of proton in a compound will appear different position in its NMR spectrum. From the position of NMR signals, we will know the nature of proton viz. Aromatic, aliphatic, acetylenic, vinylic, adjacent to electrons attracting or electron releasing group etc.,

Reason for TMS used as standard reference:

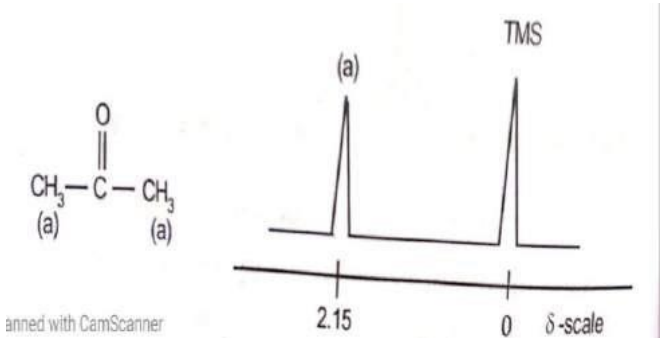
TMS, tetramethylsilane $(CH_3)_4$ Si used as reference compound in NMR, because

- It has 12 equivalent protons give a single sharp peak in its NMR spectrum
- It has a low boiling point and thus it can be easily recovered after the spectrum recorded
- It is chemically inert
- It is soluble in most of the organic solvent
- Its signal is appeared at the extreme end of the spectrum i.e. upfield, δ=0ppm.

1) INTERPRETATION OF NMR SPECTRA OF SIMPLE ORGANIC COMPOUND:

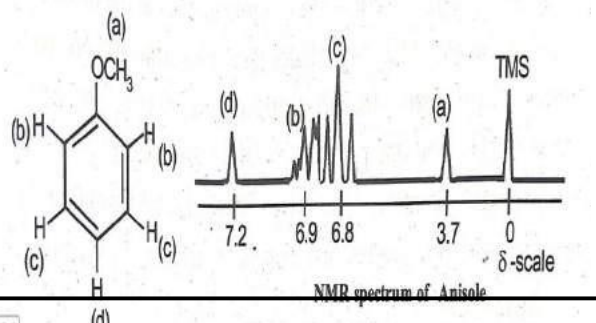
The NMR spectra of the following compound are run in $CDCl_3$ solvent

1) Acetone :



Acetone contains one sets of protons (a). This proton signal is slightly deshielded due to the carbonyl group and produced signal at the upfield. It gives a intense Sharp signal at δ=2.15 i its NMR spectrum due to six equivalent protons

2) Anisole:



NMR spectrum of Anisole

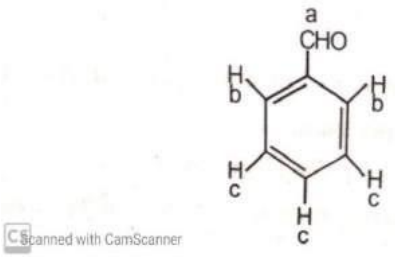
Anisole contains four sets of protons (a,b,c,and d). It gives four signals in its NMR spectrum.

- Singlet δ=3.7,3protons (-OCH_3proton Ha)
- Multiplet, δ=7.2(two ring printing meta to-OCH_3groups, Hc protons)
- multiplet, δ=6.88, (two ring proton ortho-OCH_3 group, Hb protons)
- multiple, δ=6.92, (one ring proton para to-OCH_3groups, Hd proton)

Explanation:

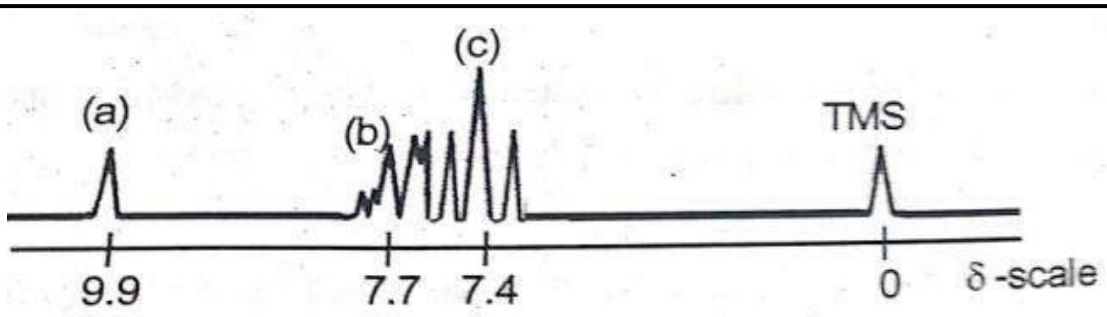
- The signal at δ=3.7is due to methoxy three equivalent protons. It does not show any coupling with the neighbouring protons and gives singlet.
- The signal at δ=7.2 is due to the two ring protons (Hc) meta to -OCH_3 group. It splits into a multiplet by neighbouring two ortho (Hb) and one para ring protons of (Hd).
- The signal at δ=6.88is due to the two ring protons ortho two -OCH_3 group, (Hb). Its splits into multiplet by neighbouring two meta protons of Hc. Since the methoxy group in anisole is electron donating group, it increases the electron density at the ortho and para hydrogen of the ring. Hence this two ortho and one para protons have greater shielding then the meta protons. These two protons, Hb and one para proton, Hd show multiplets at the upfield then the meta protons, Hc. This Hb and Hc multiplets are combined to show one broad multiplet in the NMR spectrum

3) Benzaldehyde :



Benzaldehyde contains three sets of protons (a,b,and c) and gives three signals in its NMR

- singlet,δ= 9.9, 1H(CHO proton)
- multiplet,δ=7.7,2H(two proton Ortho to -CHO)
- triplet,δ=7.4,3H(three remaining protons of the ring)



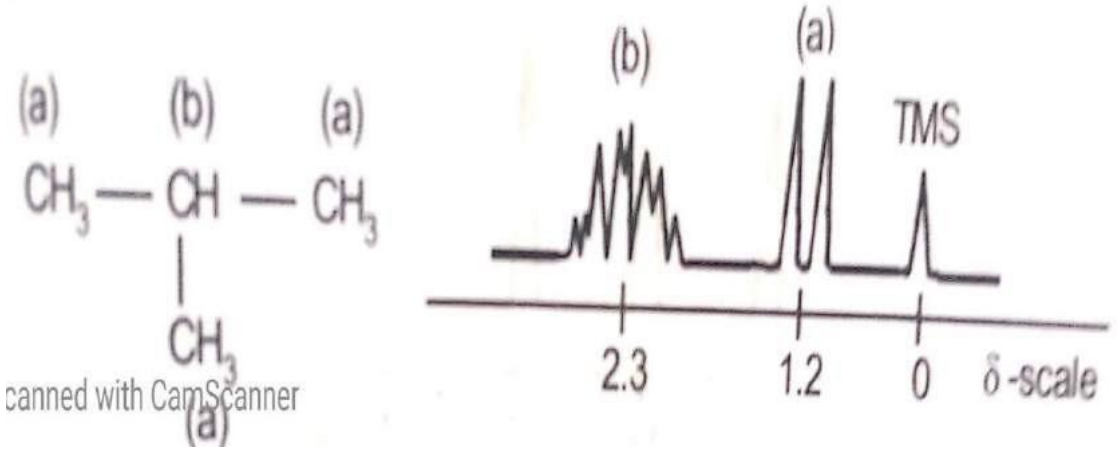
NMR spectrum of Benzaldehyde

Explanation:

- The signal of δ=9.9 (for down Field) is due to the aldehyde proton. It does not show any coupling with the neighbouring protons and gives singlet
- The signal at δ=7.7is due to the two protons oruthi to the aldehyde group (b). It splits into a multiplet by the neighbouring three proton of Hc and one Ha proton. They appear at downfield due to deshielding by anisotropic effect of the carbonyl group.

4) The signal at δ=7.4 is due to the remaining three ring protons (c). It splits into a triplet by the neighbouring two ortho Hb protons.

5) Iso- butane:



Iso- butane contains two sets of equipment protons (a&b) it gives two signals its NMR spectrum. They are

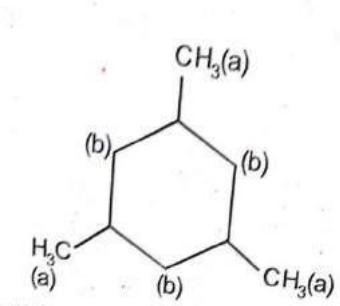
- douplet, δ=1.2, one proton
- multiplet, δ=2.3,9 protons(-3CH3)

Explanation:

The signal at δ =1.2 is due to the nine proton of the three -CH_3 group (a). It splits into a double by the neighboring one proton of CH group

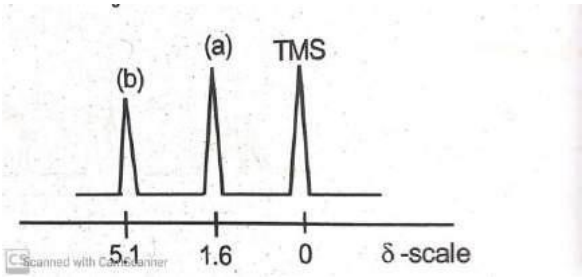
- The signal at δ= 2.3 is due to the one proton of CH group
- (b). It splits into a multiplet by the neighbouring nine proton of the three CH_3 group(a)

6) Mesitylene



Mesitylene contains two sets of protons (a &b). It gives two signals its NMR spectrum. They are,

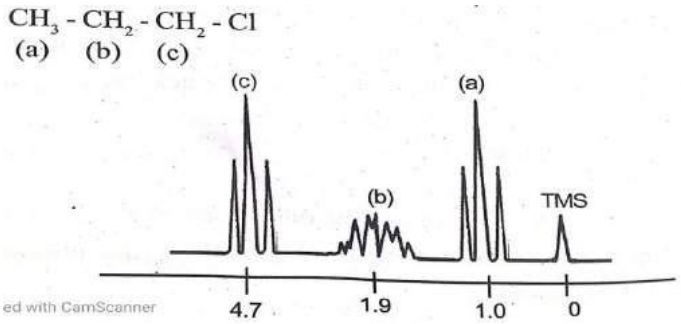
- singlet, δ=1.6,9protons (-3CH_3)
- singlet,δ= 5.1,3protons (benzenoid ring)



Explanation:

- a) The signal at δ= 1.6 is due to the nine proton of the three - CH_3 group (a)
- b) The signal at δ=5.1 is due to the three protons of the benzenoid ring.It appears at the down field.

7) 1-chloropropane: (n- propyl chloride)



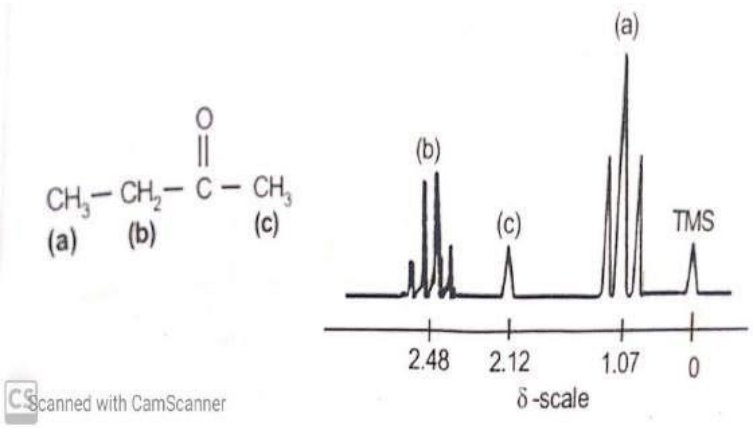
1-chloropropane contains three sets of equivalent proton (a,b and c) it gives three signals in its NMR spectrum. They are,

- triplet,δ=1.0,3 protons (-CH_3)
- multiplet,δ=1.9,2protons (-CH_2-)
- triplet,δ=4.7,2protons (-CH_2Cl)

Explanation:

- The signal at δ =1.0 is due to three protons of the -CH_3 group (a).It split into a triplet by the neighbouring two protons of -CH_2-group (b).
- The signal at δ =1.9 is due to the two protons of the-CH_2 - group (b). It splits into a quartet by the neighboring three protons of the – CH_3 group (a). Then each peak further splits into triplet by the neighbouring two protons of -CH_2Cl group (c). As a result, a multiplet is formed.
- The signal at δ =4.7 is due to the two protons of the -CH_2Cl group (c). It splits into a triplet by the neighboring two protons of the -CH_2 - group (b). It appears in the down field due to the de shielding effect of electronegative chlorine atom

8) Ethyl methyl ketone :



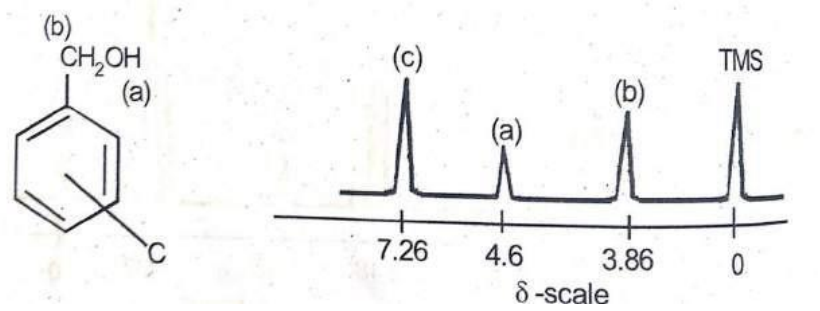
Ethylmethyl ketone contains three sets of equivalent proton (a,b&c) it gives three signals in it NMR spectrum. They are,

- triplet,δ =1.07,3 protons (-CH3)
- quartet,δ =2.48,2protons (-CH2–)
- singlet,δ =2.12,3protons

Explanation:

- The signal at δ =1.07 is due to the three protons of the -CH_3 group (a). It splits into a triplet by the neighboring two protons of the-CH_2 - group (b).
- The signal at δ=2.48 is due to the two protons of the -CH_2Group (b).It splits into a quartet by the neighboring three protein of the-CH_3 group (a).
- The signal at δ=2.12 is due to the three protons of the group (c). It does not undergo any splitting and appears as a singlet
- Due to the deshielding effect of oxygen in the carbonyl group both signal (b) & (c) appear in the slightly down field then the normal -CH_2 - and -CH_3 group position

9) Benzyl alcohol:



Benzyl alcohol contains three sets of equivalent proton (a, b &c). It gives three signal in it NMR spectrum. They are

- singlet δ =4.6protons (-OH)
- singlet δ=3.86, 2proton (-CH2-)
- singlet δ= 7.26,5 protons (-C2H5)

Explanation:

- The signal at δ = 4.6 is due to the one proton of -OH group (a). It does not undergo splitting and appear as a singlet. It appears in the down field due to the de shielding effect of its oxygen.
- The signal at δ= 3.86 is due to the two proto s of the -CH_2 group (b). It does not undergo splitting and appears as a singlet. It appear in down field due to the de shielding effect of oxygen of the neighboring-OH group (a).
- δ=7.26 is due to the symmetric five proton of the benzene ring does not undergo splitting and gives intense singlet signal in the down field.