Name of Unit	Benzene and its Derivatives
Subject /Course Name	Pharmaceutical Organic Chemistry-II
Subject/Course ID	BP301T
Module no.	1
Class:B.Pharm. Semester	3rd
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Learning Outcome of Module-1

LO	Particular	Course Outcome Code
LO1.	Students are able to understand about in detail the concept of structure of benzene.	BP301.1
LO2.	To gain knowledge about the Aromaticity of Benzene.	BP301.1
LO3.	To understand about the Reactions of benzene.	BP301.1
LO4.	To understand about effect of substituents on reactivity and orientation of mono substituted benzene.	BP301.1

Module Content Table

No.	Topic
1.	Introduction ofBenzene and Its Derivatives.
2.	Analytical,Synthetic and other evidences in the derivation of structure of benzene.
3.	Orbital Picture and Resonance in Benzene.
4.	Aromatic Characters (Huckel'rule).
5.	Reactions of Benzene: -Nitration, Sul phonation, Halogenation-reactivity, Frieda crafts Alkylation-reactivity, limitations, Frieda crafts acylation.
6.	Introduction about Substituents.
7.	Effect of Substituents on Reactivity and Orientation of Mono Substituted Benzene Compounds.
8.	Structure and uses of DDT, Saccharin, BHC and Chloramine.

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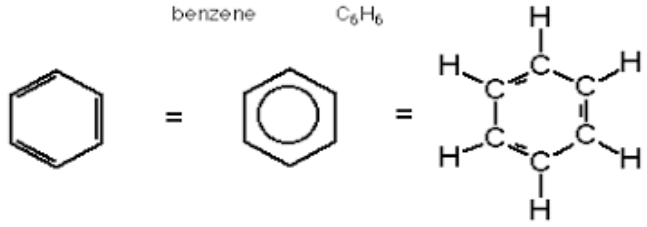
INTRODUCTION OF BENZENE: -

Benzene and all those compounds which resemble benzene in their chemical behaviour are termed as aromatic. Benzene is an aromatic compound having molecular formulae C_6H_6. The benzene molecule is composed of six carbon atoms joined in a planar ring with one hydrogen atom attached to each. Because it contains only carbon and hydrogen atoms, benzene is classed as a hydrocarbon



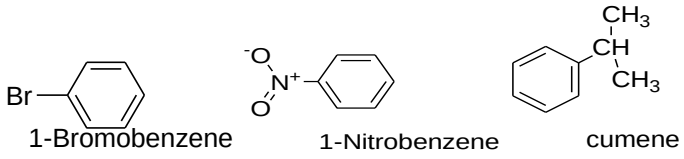
Benzene is a chemical that is a colorless or light yellow liquid at room temperature. It has a sweet odor and is highly flammable. **Benzene** evaporates into the air very quickly. Its vapor is heavier than air. **Benzene** dissolves only slightly in water and will float on top of water.

Nomenclature of Derivatives of Benzene: -

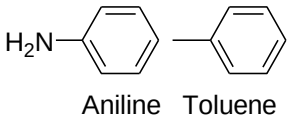
In **IUPAC** nomenclature there are various rules for naming benzene derivatives. These are as follows: -

For Monosubstituted benzene derivatives: -

(a) Name of monosubstituted benzene derivative is obtained by placing prefix (name of substituent) to the word benzene.For example,

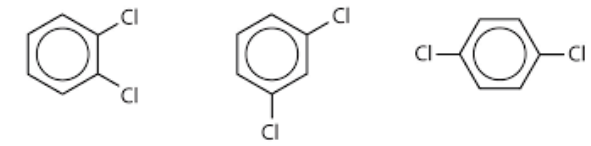


(b) Some derivatives have special names like: -

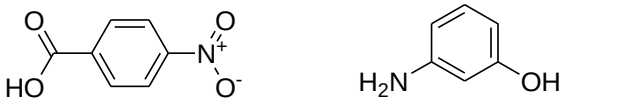


For DisubstitutedBenzene Derivative: -

(a) **Derivatives having two similar groups**, the prefix "di" is added before the name of the group and the relative positions of the two groups are indicated by the symbol 'O' (ortho) for 1,2 ; 'M' (meta) for 1,3 and 'P'(para) for 1,4 positions respectively. For example,



(b) Derivatives having different groups are named as a derivativesof the compound with the main functional group at the position 1. For example,



Structure of Benzene: -

The structure of benzene has been derived as follows: -

Analytical Evidence: -

A) Molecular formula: -

(1) Elemental analysis and molecular weight determination showed that benzene had the molecular formula C_6H_6.

2) This indicated that benzene was a highly unsaturated compound (compare it with n-hexane,C_6H_{14}).

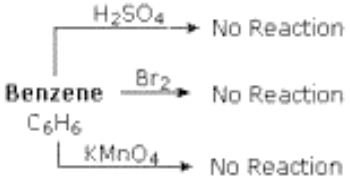
Synthetic Evidences: -Straight -chain structure not possible

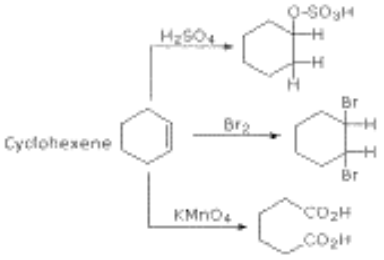
(1) Benzene could be constructed as a straight -chain or ring compound having double(C=C) and /triple bonds.

(2) But benzene did not behave like alkenes or alkynes.

(3) It did not decolorize bromine in carbon tetrachloride or cold aqueous potassium permanganate .

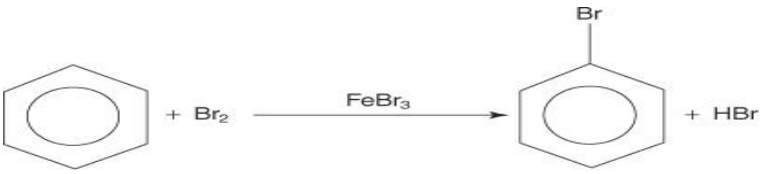
(4) It did not add water in the presence of acids.





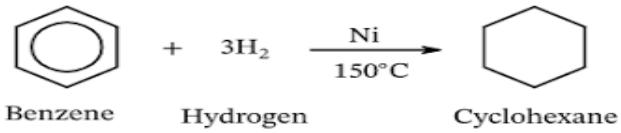
Evidence of Cyclic Structure: -

(1) **Substitution of Benzene**:- Benzene reacted with bromine in the presence of $FeBr_3$(catalyst) to form monobromobenzene.

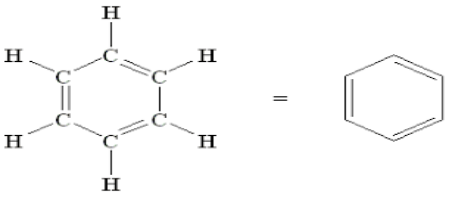


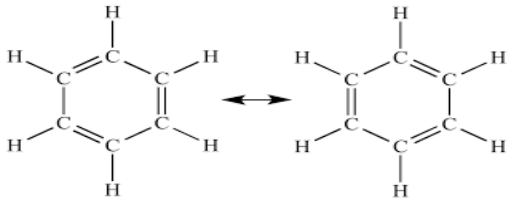
The fact that only one monobromo and no isomeric products were obtained indicated that all six hydrogen atoms in benzene were identical. This could be possible only if benzene had a cyclic structure of six carbons and to each carbon was attached one hydrogen.

2. Addition of Hydrogen:-Benzene added three moles of hydrogen in the presence of nickel catalyst to give cyclohexane.



Kekule'structure Of Benzene:- In 1865,Kekule suggested that benzene consisted of a cyclic planar structure of six carbons with alternate double and single bonds. To each carbon was attached one hydrogen. Benzene according to this proposal, was simple 1,3,5-cyclohexatriene.





Kekule's structure of benzene explained satisfactorily the following points.

1.That benzene contains three double bonds.

2.That all six hydrogen atoms in benzene are equivalent,and benzene gives only one monosubstituted product,C_6H_5X.

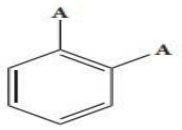
3. That there are three possible disubstituted products of benzene(ortho,meta,para).

Objections to Kekule'sStructure:-

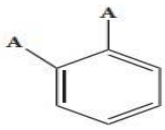
The structure of benzene postulated by Kekule could not explain the following facts:

1.From the Kekule's structure, one should expect that benzene due to the presence of three double bonds should show chemical properties similar to alkenes but it does not do so. Benzene does not decolorize the purple color of alkaline $KMnO_4$ or orange red color of bromine water.

2.On the basis of Kekule's structure, two orthodibromobenzene are possible. The two carbon atoms to which the Br atoms attached are linked by a single bond in one structure and by a double bond in another .In reality ,only one ortho dibromo benzene is known.

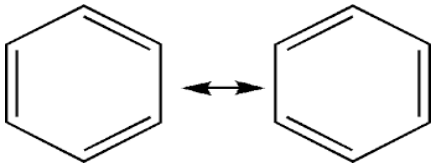


Presence of double bond between the substituents



Presence of single bond between the substituents

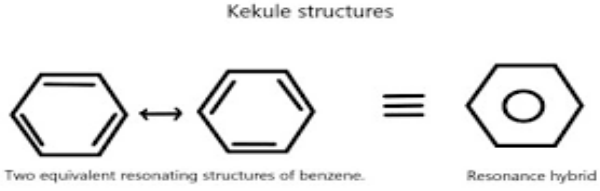
In order to explain this, Kekule's postulated that benzene may be considered as a mixture of two rapidly interconverting forms in which the single and the double bonds rapidly interconvert.



3.The suggestion that benzene molecule is having three alternate double bonds is not correct.

Resonance Structure of Benzene: -

In the case of benzene, Kekule's structures (1) and (2) represent the resonance structures. Actual structure of the molecule may be represented as hybrid of these two resonance structuresor by the single structural formula (3).

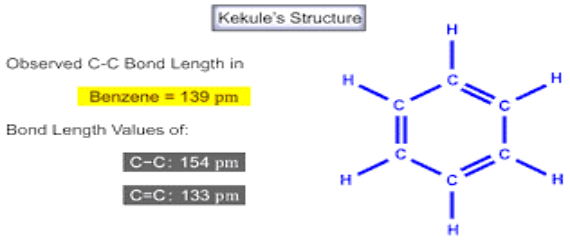


It should be clearly understood that the resonance structures (1) and (2) are not the actual structures of the benzene molecule. They exist only in theory. None of these structures

adequately represents the molecule. In resonance theory, we view benzene molecule as being hybrid of these two hypothetical resonance structures.

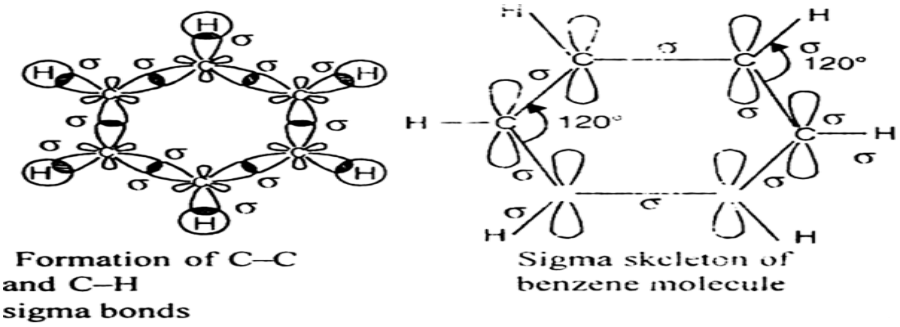
Look at the structures (1 and 2) carefully. All single bonds in structure (1) are double bonds in structure (2), that is consider a hybrid of them. Then the C-C bonds in benzene are neither single bonds nor double bonds. Rather, they are something halfway between.

When experimentally exactly find. Spectroscopic measurements show benzene is planar and that all of its C-C bonds are of equal length, 1.40A°. This value lies between the C-C single bond length (1.54A°) and the C-C double bond length (1.34A°).



Resonance hybrid is more stable than any of its contributing structures. For benzene, the stability due to resonance is so great that π- bonds of the molecule will normally resist breaking. This explains lack of reactivity of benzene towards addition.

Molecular Orbital Structure of Benzene: - The structure of benzene is best described in terms of the modern molecular orbital theory. All six carbon atoms in benzene are sp^2 hybridized. The sp^2hybrid orbitals overlap with each other and with s orbitals of the six hydrogen atoms forming C-C and C-H σ bonds.



Formation of C–C and C–H sigma bonds

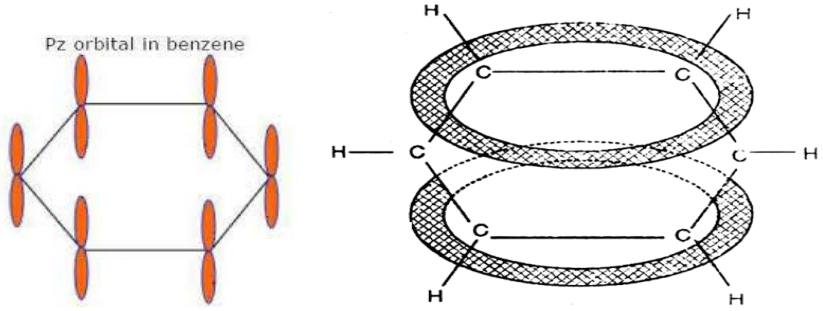
Sigma skeleton of benzene molecule

Formation of σ- bonds in benzene

Since the σ- bonds result from the overlap of planar sp^2 orbitals,all carbon and hydrogen atoms in benzene lie in the same plane. All σ- bonds in benzene lie in one plane and all bond angles are 120°.

Also, each carbon atom in benzene possesses an unhybridized p-orbital containing one electron. These p- orbitals are perpendicular to the plane of σ- bonds. The lateral overlap of these p-

orbitals produces a π molecular orbital containing six electrons. One half of this π molecular orbital lies above and the other half lies below the plane of the σ- bonds



The six electrons of the p orbitals cover all the six carbon atoms, and are said to be delocalized. As a result of delocalization is formed a stronger π- bond and a more stable molecule. Thermochemical data has actually shown that the stabilization energy of a delocalized π molecular orbital, as in benzene, is 36 kcal/mole compared to the p-orbitals forming three ordinary π-bonds as in 1,3,5- cyclohexatriene.Thus benzene gives substitution reactions in which the stability of the benzene ring is retained.

Resonance Energy of Benzene: -

Benzene's special stability is due to the formation of the delocalized π molecular orbital. The magnitude of this extra stability can be estimated by measuring the changes in heat of hydrogenations that are associated with reactions. Hydrogenation of cyclohexane evolves 28.6 kcal/mol, a value typical for hydrogenation of alkenes.

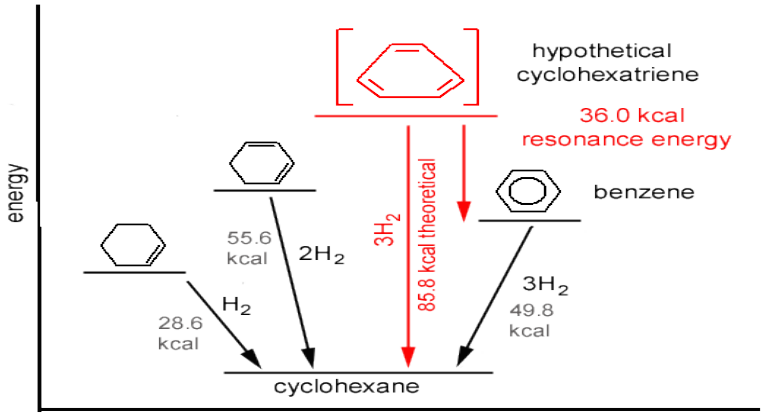


Fig. makes theseenergy relationship more evident. The 36kcal difference between the heat evolved in the hydrogenation of benzene and that estimated for hydrogenation of a compound with three ordinary double bonds is added stability. This added stability is sometimes called Resonance Energy.

Resonance energy is a measure of how much stable a resonance hybrid structure is than its extreme resonance structures.

Aromaticity (Huckel Rule): -The aromatic compounds apparently contain alternate double and single bonds in a cyclic structures, and resemble benzene in chemical behaviour. They undergo or Aromaticity.

Aromaticity: -It is, in fact, a property of the sp^2 hybridized planar rings in which the p orbitals (one on each atom)allow cyclic delocalization of π electrons.

Criteria for Aromaticity:- On the basis of the above considerations, can be laid down criteria or rules which help us in knowing whether a particular compound is aromatic or non- aromatic.

Rule 1. An aromatic compound is cyclic and planar.

Rule 2. Each atom in an aromatic ring has a p orbital. These p orbitals must be parallel so that a continuous overlap is possible around the ring.

Rule 3. The cyclic π molecular orbital (electron cloud) formed by overlap of p orbitalsmust contain (4n+2) π electrons, where n= integer 0, 1,2,3 etc. This is known as Huckel Rule.

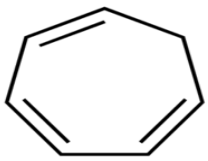
Let us apply these rules to the following examples:

Benzene:- It is a cyclic and planar compound. It has a p orbital on each carbon of the ring involved in a double bond. It has three double bonds and six π electrons, which is in accordance with Huckel rule.

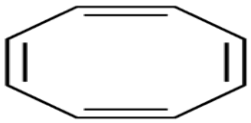
4n+2 =6 or 4n=6-2

4n=4 and n=1

Cycloheptatriene:- It is cyclic and planar. It has three double bonds and six π electrons. But one of the carbons is saturated and does not possess a p orbital. Hence a continuous overlap around the ring is not possible. This compound is, therefore, non- aromatic.



Cyclooctatetraene:- It is cyclic and has a p orbital on each atom of the ring. The Huckel rule is not satisfied, since there are 8π electrons.



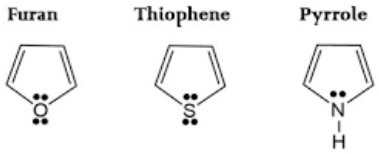
4n+2=8 or 4n=8-2

4n=6 and n=1.5

The compound is non-aromatic. Moreover, it has been determined that cyclooctatetraene is not planar but tub- shaped.

Heterocyclic Aromatics:-Heterocyclic compounds also behave as aromatic if they obey the aromaticity rules. Examples of such heterocyclics are

Let us first consider the 5-membered heterocyclic compounds Pyrrole, Furan and Thiophene.



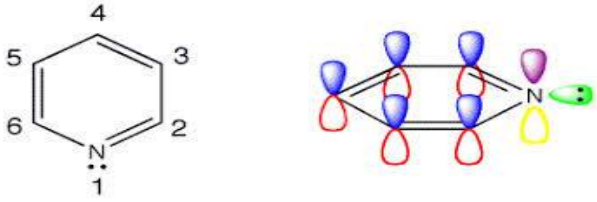
Applying aromaticity rule we find:

1. They are cyclic planar.
2. Each has a p orbital on every ring atom.
3. Each follow Huckel'rule.

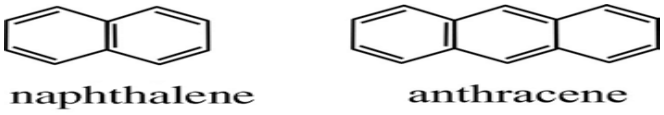
In pyrrole, the N atom (also sp^2hybridized) has an unused pair of electrons in a p orbital parallel with other four p orbitals. The four p electrons of carbons and the two electrons of N atom form a cyclic π molecular orbital.

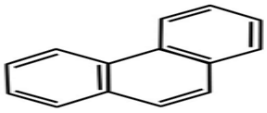
In furan and thiophene, there are four p orbitals on the four carbons, containing one electron each. However, in furan and thiophene, there are two unused electron pairs with O or S atom. One of these is in a p orbital at right angles to the ring and is not to be counted.

Similarly, in pyridine with three double bonds, each ring atom has a p orbital, and six electrons form the π MO. Therefore, the compound is aromatic. The unshared electron pair on nitrogen is perpendicular to the ring and is not to be counted while applying Huckel's rule.



Polycyclic compounds: -some polycyclic compounds are also aromatic. For example, Naphthalene contain 10π electrons(n=2), Anthracene and Phenanthrene has 14π electrons(n=3) and are aromatic.





Chemical Reactions of Benzene:- Resonance provides extra stability to benzene and other aromatic compounds. So all these compounds shows substitution reaction rather than addition reactions. These substitution reactions are carried out by using reagents which are electrophilic in nature as benzene has π electrons. Benzene has two π – electron clouds which are loosely held above and below the n of the ring and are easily available to electrophiles. Benzene acts as a nucleophile and easily reacts with electrophiles. Benzene shows aromatic electrophilic substitution reaction.

Electrophilic Aromatic Substitution Reactions:-

1.Halogenation

2.Nitration

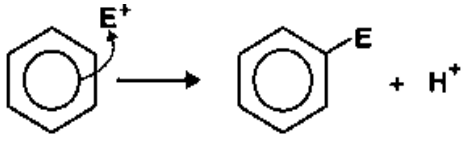
3.Sulfonation

4.Friedel -Craft Alkylation

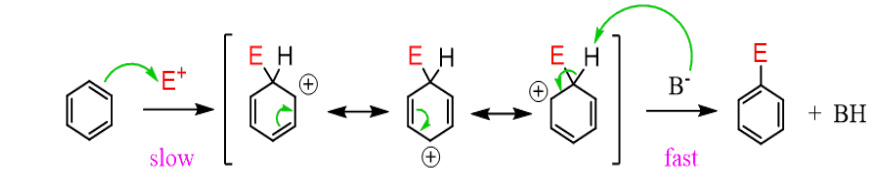
5.Friedel -Craft Acylation.

Aromatic Electrophilic Substitution Reactions of Benzene takes place in two different ways:

1.Concerted Reactions:- This reaction takes place in single step. It involves simultaneous formation of new covalent bond between C atom of the ring and the electrophile and breakage of C-H bond.



2.Two Step Process:- In the first step, electrophile adds to the benzene ring and forms a carbocation intermediate and in the second step and the intermediate losses a proton to give the substitution product. Any step may be rate determining step.



Steps1. Addition of the electrophile- Making the C-E bond

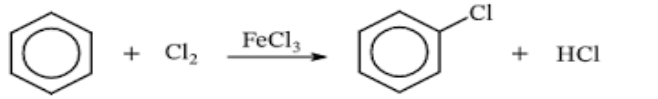
Sigma Complex

Resonance stabilized Arenium ion

Step 2. Proton transfer- Restoring Aromaticity

On the basis of various observations and the facts it was found that electrophilic substitution occurs through second mechanism i.e. by two step process. The formation of carbocation intermediate from benzene is much higher than that from alkenes and hence benzene reacts at a slower rate than alkenes.

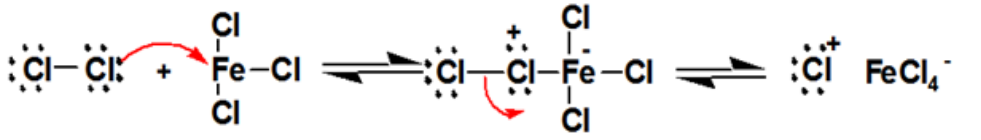
1.Halogenation: - Benzene reacts with chlorine in the presence of $FeCl_3$or $AlCl_3$ at room temperature to form chlorobenzene. Iron powder can be used to in place of ferric chloride.



Mechanism:- Following steps are involved:

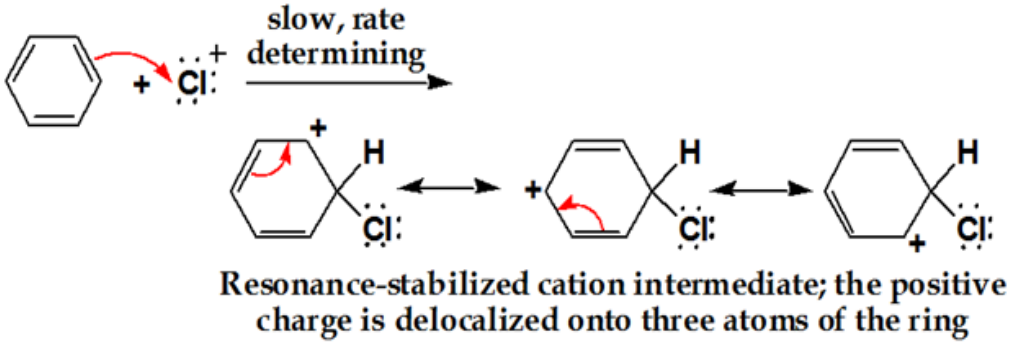
First step: - Formation of the electrophile

Chloronium ion formation, chlorine react with the Lewis acid to form a complex which makes the chlorine more electrophile.



Second step:

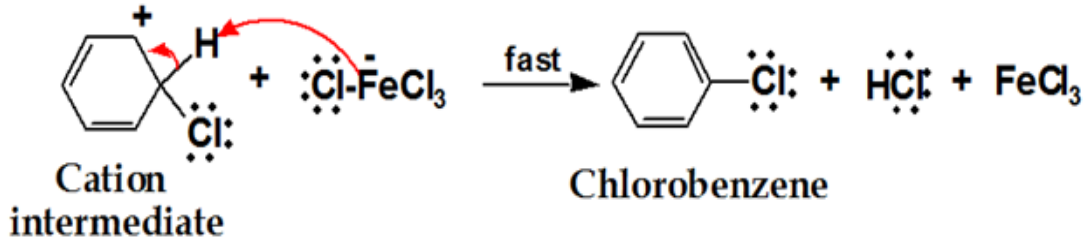
Chloronium ion attack on the ring. The double bond electrons of the aromatic C=C act as a nucleophile, attacking the electrophilic Cl, and delocalization take place.



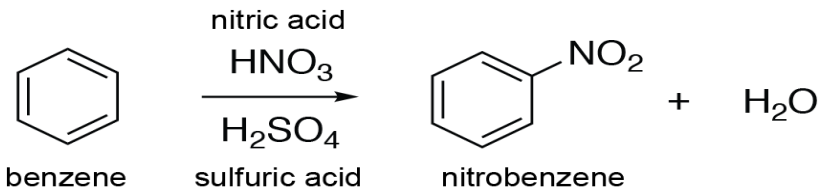
Resonance-stabilized cation intermediate; the positive charge is delocalized onto three atoms of the ring

Third step:

Proton transfer regenerates the aromatic character of the ring.



2.**Nitration: -**Benzene reacts with concentrated ed nitric acid in the presence of concentrated sulfuric acid at 60°C to form nitrobenzene.



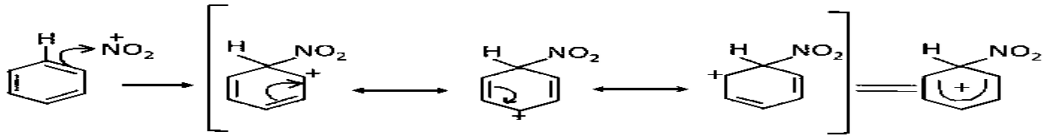
Mechanism: - Following steps are involved:

Step1: -

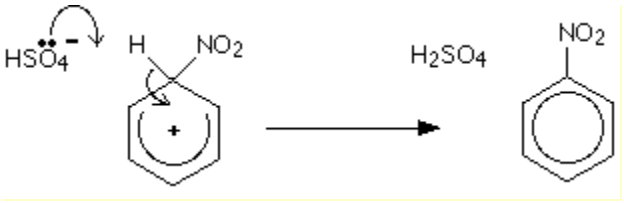
The formation of the electrophile

The electrophile is the "nitronium ion" or the "nitryl cation", NO2+. This is formed by reaction between the nitric acid and the sulphuric acid.

Step2: -The electrophile attacks the benzene ring to form a carbonium ion.



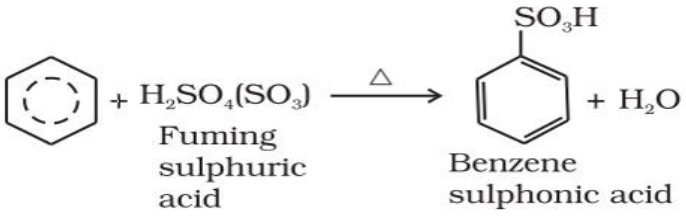
Step 3: -Loss of proton yields nitrobenzene



This step is fast and hence does not affect the rate of the reaction.

3.Sulfonation:- Benzene reacts with concentrated sulfuric acid at 120°C or fuming sulfuric acid at room temperature to give benzenesulfonic acid.

Note:- Fuming sulfuric acid is concentrated sulfuric acid that contains added sulfur trioxide.

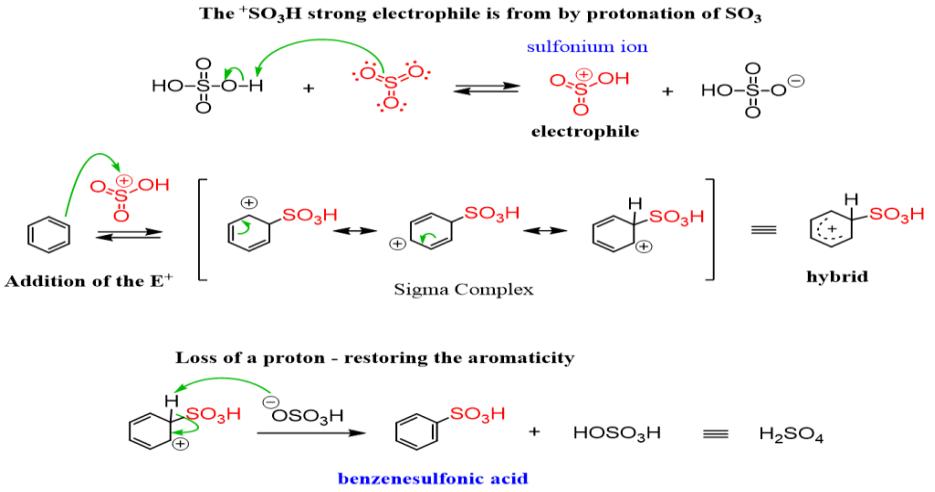


Mechanism:- Following steps are involved:

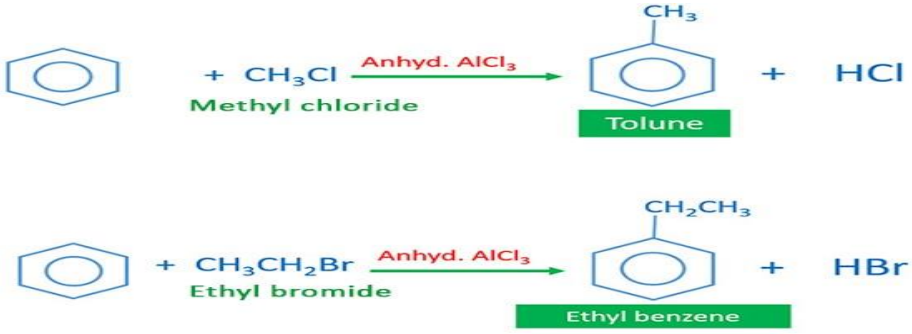
Step1:-Electrophile is formed. In this reaction the electrophile is sulfur trioxide(SO_3). In concentrated sulfuric acid, SO_3 is produced as follows. In fuming sulfuric acid, this step is unimportant because the dissolved SO_3 reacts directly.

Step 2:- The electrophile attacks the benzene ring to form a carbonium ion.

Step 3:- Loss of a proton and get benzenesulfonic acid.



4.Friedel- Craft Alkylation:- Benzene reacts with alkyl halides in the presence of aluminum chloride to form alkylbenzenes. For example,

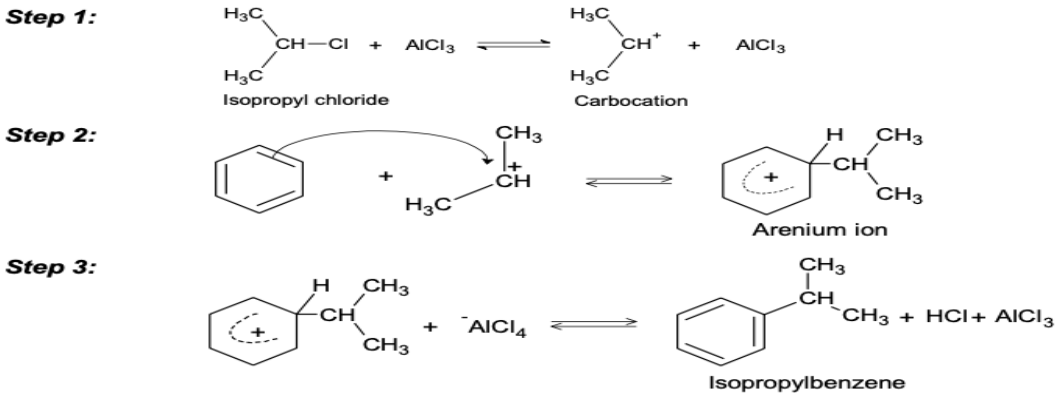


Mechanism:-Following steps are involved:

Step 1:- Formation of the electrophile(CH_3^{+}).

Step 2:- The electrophile attacks the benzene ring to give a carbonium ion.

Step 3:- loss of proton gives alkylbenzene.

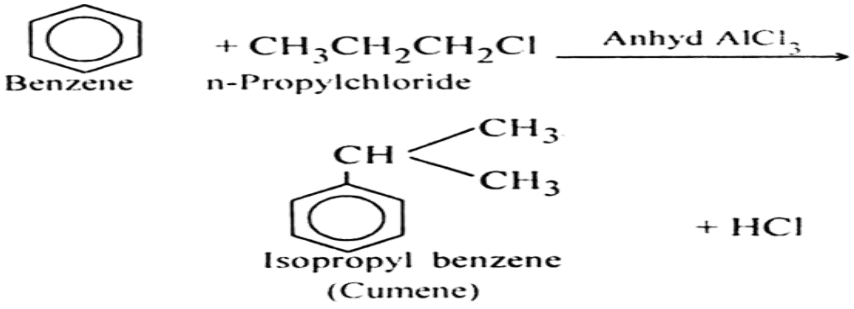


Limitations of Friedel-Craft Alkylation:- Friedel-Craft Alkylation has following two major drawbacks:

1. Formation of Polysubstitution Products:- F.C. alkylation leads to the formation of polysubstituted products as the new one alkyl group activates the ring towards second substitution by increasing the electron density in the ring due to its electron denoting capacity. For example,

This draw back can be avoided by using an excess of aromatic compound.

2. The alkyl groups often tends to rearrange. For example,When benzene is treated with n-propyl chloride in the presence of $AlCl_3$, the product is isopropyl (also called cumene) rather than the expected n- propyl benzene.



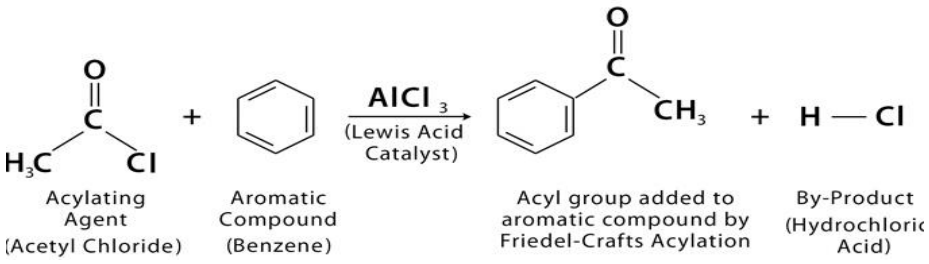
This is because the Friedel- crafts alkylation involves formation of carbonium ion electrophiles. These carbonium ions can undergo rearrangement before attacking the benzene ring.

Other limitations:- 1. Aryl halides cannot be used in the place of alkyl halides.

2.Aniline and other aromatic compounds do not undergo F.C. alkylation.

3.F.C. alkylation cannot be carried out on nitrobenzene as nitro group has strong deactivating effect.

5.Freidel-crafts Acylation:- Benzene reacts with acid chlorides (or anhydrides) in the presence of aluminum chloride to give aromatic ketones. For example,

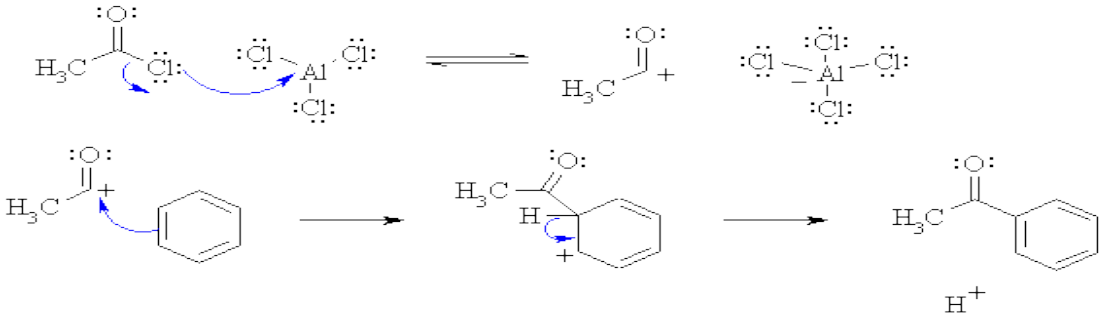


Mechanism:- Following steps are involved:

Step 1: -Formation of the electrophile (CH_3CO).

Step 2: -The electrophile attacks the benzene ring to form a carbonium ion.

Step 3: - Loss of proton gives an aromatic ketone.



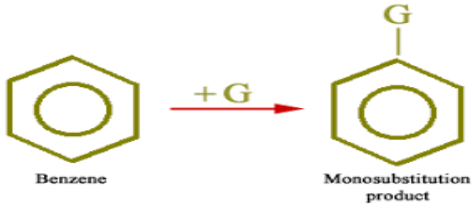
$$H^+ + AlCl_4^- \longrightarrow HCl + AlCl_3$$

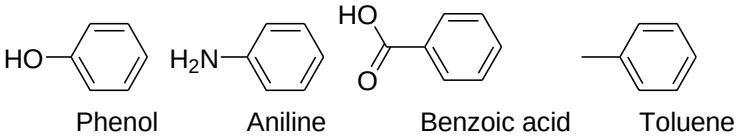
Substituents and Effect Of Substituents On Reactivity And Orientation Of Mono Substituted Benzene: -

Substituents:- an atom or group of atoms taking the place of another atom or group or occupying a specified position in a molecule.

Substitution in Monosubstituted Benzene

All hydrogen atoms of the benzene ring are equivalent. Therefore, only one monosubstitution product(C_6H_5-G) is possible.



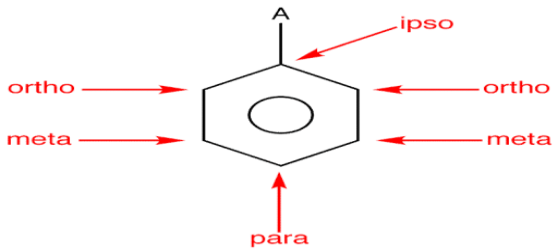


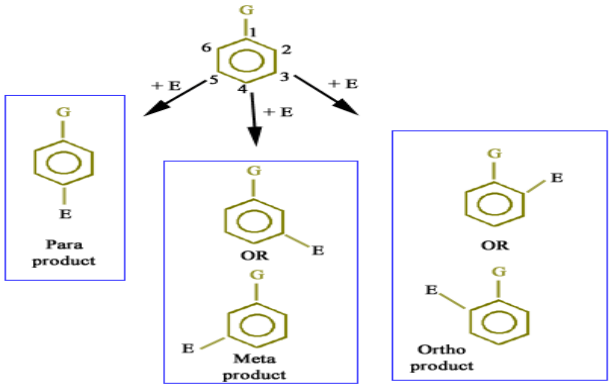
A Second substituents,E can occupy any of the remaining five positions.

1.The position 2 and 6 are equivalent,and would give the ortho product.

2.The position 3 and 5 are equivalent, and would give the Meta product.

3.The position 4 is unique and would give the Para product.





Two Types of Influence of Substituents:-

A substituent's (S) already present on the benzene ring exercises two types of influence on further substitution.

1. Directive or Orientation Effect:- The first substituents (S) may direct the next incoming substituents (E) to ortho, meta or para position, depending on the nature of the substituent. This is called the Directive or the Orientation (Orient= to arrange) Effect.

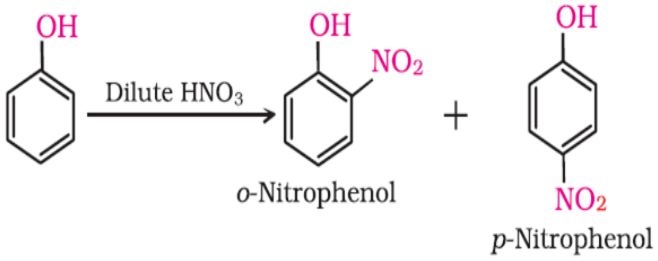
2. Activity Effects:- The substituents already present may activate or deactivate the benzene ring toward further substitution. These effects are called the Activate Effects.

1. Directive Effects of Substituents:-

We have seen that in the monosubstituted benzene,C_6H_5-S, there are five available hydrogens. Of these two are ortho, two meta and one para to S. It is determined by the nature of the first substituents on the ring.

Ortho-Para Directing Effect:- Certain substituents direct the second substituent to the ortho and para position simultaneously. These are called Ortho-Para Directors.

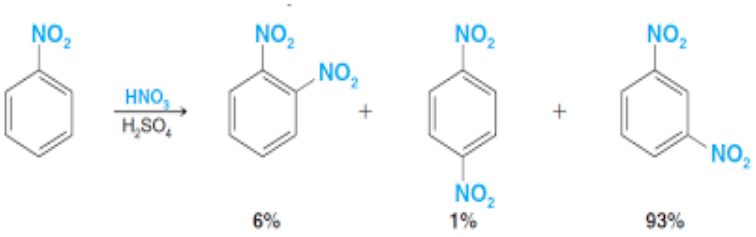
For example, When phenol is nitrated, the only products obtained are o-nitrophenol(53%) and p-nitrophenol(47%), and no meta isomer is produced.



The substituents -OH is said to have directed the -NO_2 group to ortho and para positions on the ring. Therefore, -OH is designated as Ortho-Para Director.

Meta- Directing Effect:-The substituents which direct the second incoming substituents primarily to the meta position, are referred to as Meta -Directors.

For example, nitration of nitrobenzene gives 93% of m-dinitrobenzene, and only 6% of ortho and 1% of p-dinitrobenzene.



Thus the substituent -NO_2 group, which has directed the second -NO_2 group to the meta position, is designated as Meta -Director.

Ortho-Para And Meta Directing Groups

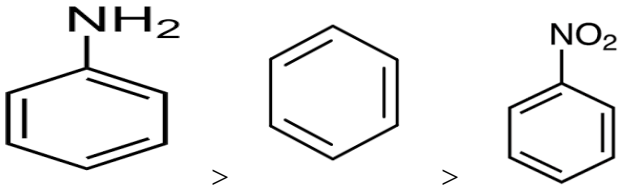
Ortho- Para Directors	**Meta Directors**
-F,Cl, -Br,-I	**NO_2**
-OH	**SO_3H**
-OCH_3	**CN**
NH_2	**COOH**
NHR,NR_2	**CHO**
CH_3,C_2H_5,R	**COR**
	NH_3^+

(2) **Activity Effect:** -Substituents already present on a benzene ring not only directs the position of an incoming group, but also influences the rate of reaction.

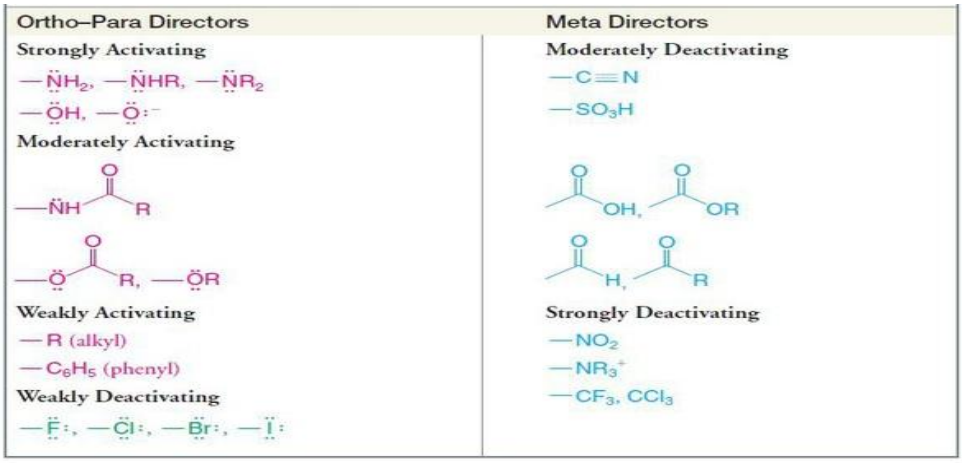
For example, toluene C_6H_5-CH_3, is nitrated 25 times faster than benzene itself.On the other hand, the rate of nitration of chlorobenzene,C_6H_5-Cl, is 30 times less than benzene. This means that the presence of CH_3 on the benzene ring activates it to aromatic electrophilic substitution, while the presence of a -Cl group deactivates it.

A substituent which activates the aromatic ring to further substitution, is called an **Activating Substituent or Ring Activator.**

A substituent which deactivates the aromatic ring to further substitution, is called a **Deactivating Substituent or Ring Deactivator**.



NH_2 Activating group NO_2 Deactivating

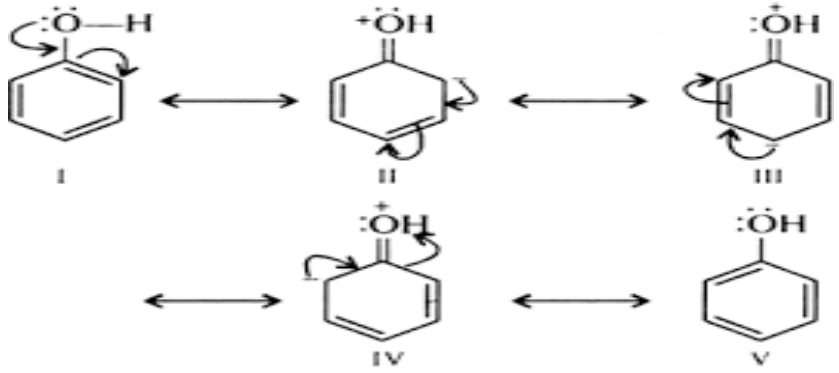


Ortho-Para directors activate a ring towards electrophilic substitution, whereas meta directing groups deactivate a ring towards electrophilic substitution.

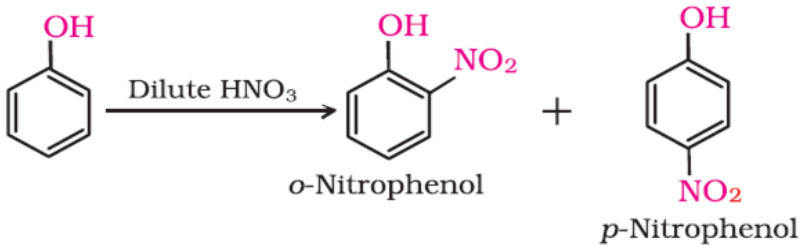
Although -F,-Cl,-Br and -I are ortho- para directors, these substituents deactivate an aromatic ring in electrophilic substitution.

Theory Of Directive Effects:-

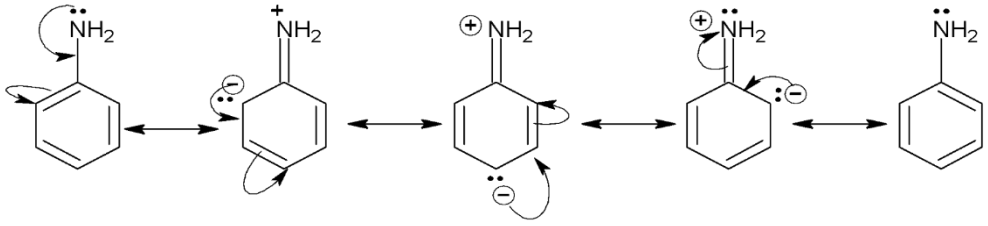
The resonance theory clearly explains why certain substituents are Ortho-Para directing, while others are Meta- Directing. Let us examine the various resonance forms of phenol, in which the substituent-OH is strongly ortho-para directing.

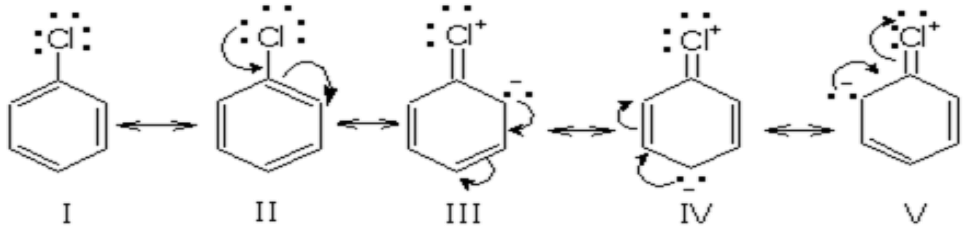


There are two nonbonding electron pairs on the oxygen atom attached to the ring. One of these is distributed into the ring by interaction with the π system as shown above. In the resonance forms, the ortho-para positions have a greater electron density than does the meta positions. Therefore, the resonance hybrid has negative charges in the ortho and para positions with electron delocalization. The electrophile (E^+) would naturally attack at these electron-rich centers regardless of its nature.



Similarly, the ortho-para directive influence of -NH_2 and -Cl groups can be explained by the resonance theory. The nitrogen atom of -NH_2 group and the -Cl atom possess a nonbonding electron pair, which is distributed into the ring.

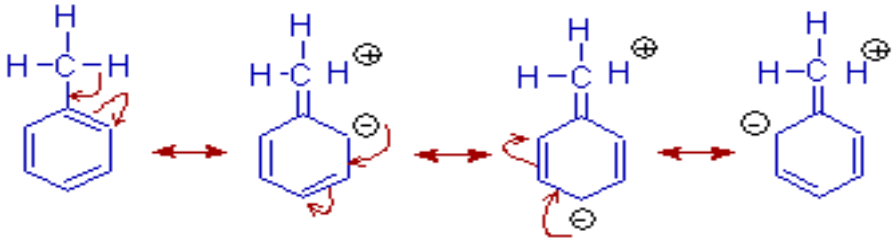




All ortho-para directing substituents or groups, posses a nonbonding electron pair on the 'key atom'.

Methyl group is an Exception:- The only exception to the above rule is the methyl or alkyl group. It is ortho-para directing, although it has no nonbonding electron pair on the key atom, carbon.

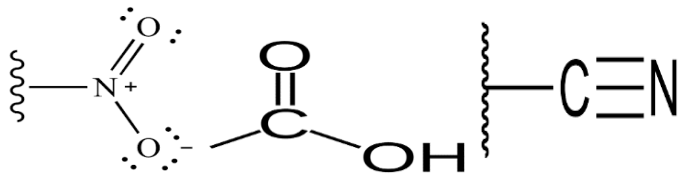
The ortho-para directive influence of CH_3 group is explained on the basis of special type of resonance called Hyperconjugation or 'No Bond Resonance'. It postulates the interaction of σ electrons instead of the usual nonbonding electron pair of the key atom. Thus the resonance structures of toluene may be written as:



Hyperconjugation in toluene

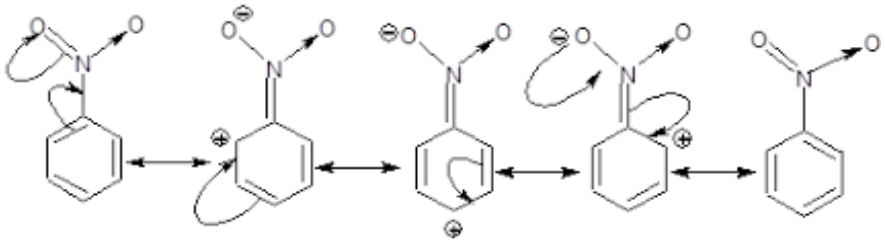
Evidently, the ortho and para positions will be the centers of electrophilic attack.

Resonance Theory and Meta- Directing Effect:- Let us first examine the structures of some common meta-directing substituents.

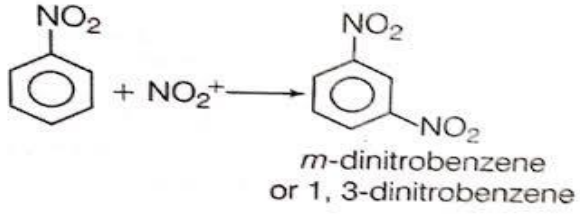


Nitro group carboxylic acid cyano group

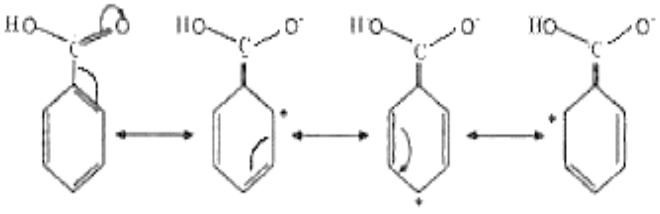
The key atom in these substituents is bonded to another highly electronegative atom by a double or triple bond. The electronegative atom pulls the electron pair of the multiple bond and thus places a positive charge on the key atom. The key atom in turn withdraws electrons from the benzene ring causing resonance. The nitrobenzene is a resonance hybrid of the following canonical forms.

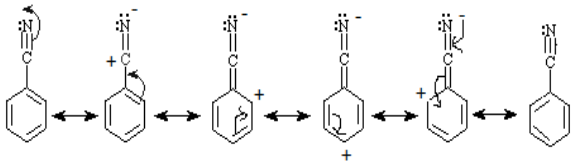


Notice that the ortho and para positions of the resonance forms have a positive charge and there is no scope of electrophile (E^+) attack at these positions. The electrophile attacks the meta positions which are relatively electron rich.



Carboxylic acid and benzonitrile show resonance analogous to nitrobenzene. The resonance hybrid having positive charge on the ortho and para positions is attacked by the electrophile at the meta positions.

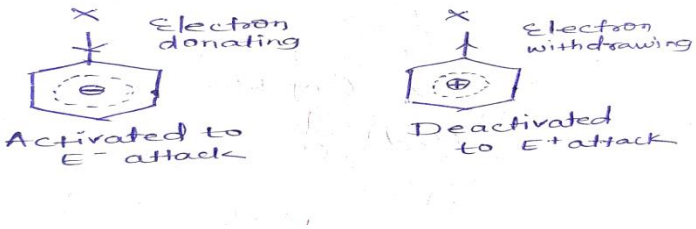




Theory of Activating and Deactivating Effects:-

The rate of electrophile aromatic substitution depends on the availability of electrons in the benzene ring. If the ring is electron rich(negative), the electrophile attack is faster. If the ring is electron -deficient (positive), the attack is slower.Thus an electron donating or electron releasing substituents will activate the aromatic ring towards electrophilic substitution. while an electron-withdrawing substituents will deactivate it.

The ortho -para directing groups (OH, NH_2, CH_3) release electrons into the ring by resonance, making it electron rich, favoring the ortho-para positions in particular.Thus the **ortho-paradirecting substituents are also ring activators.**



The meta- directing groups(NO_2,SO_3H,COOH), withdraws electrons from the ring by resonance , making it electron -deficient. Therefore, Meta-Directing groups are ring deactivators.

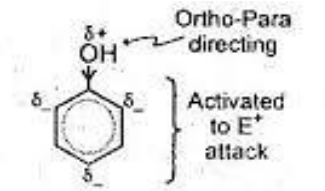


Fig. 34.2. Ortho-para directing substituents being electron-releasing activate the ring to electrophile attack..

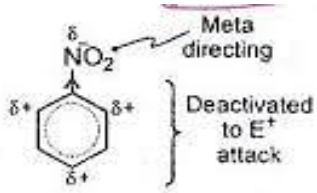
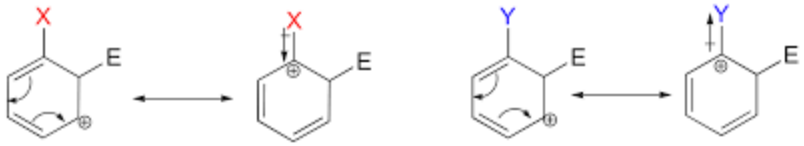


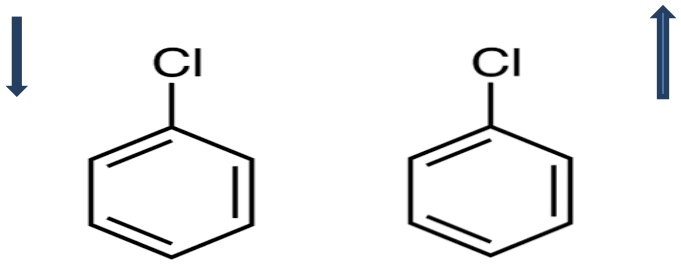
Fig. 34.3. Meta-directing substituents being electron-withdrawing deactivate the ring to electrophile attack.



X = electron donating group: stabilizes the intermediate, activates the ring

Y = electron withdrawing group: ***de***stabilizes the intermediate, ***de***activates the ring

Anomalous Behavior of Halogens: -Halogens, although ortho-para directorsare ring deactivators. This anomalous behavior of halogens is attributed to the fact that there are two opposing effects operating. A halogen substituent is electron-releasing by resonance but electron -withdrawing because of its high electronegativity (inductive effect). The inductive effect dominates the resonance effect, and the net results is that the ring is rendered electron- deficient and less liable to electrophilic attack.



(a) (b)

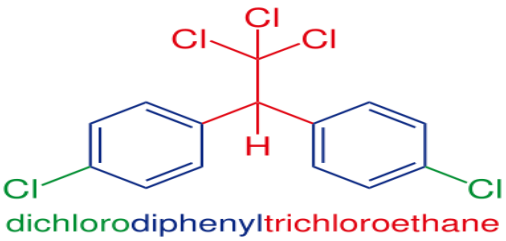
(a) Cl release electrons intothe ring by resonance and increases its electron density.

(b) Higher electronegativity of Cl, decreases the electron -density of the ring by inductive effect.

Structure and Uses: -

DDT(DiChloro Diphenyl Trichloro Ethane)

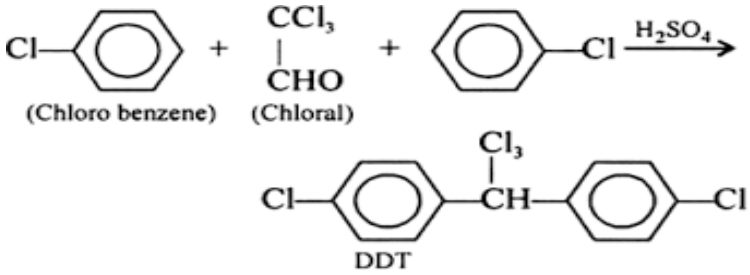
Structure



The IUPAC name of DDT is **1,1′-(2,2,2-trichloroethane-1,1-diyl)bis(4-chlorobenzene).**Its molecular formula **is $C_{14}H_9Cl_5$**.

Properties:- DDT is a crystalline chemical compound, which is a **colorless, tasteless, hydrophobic, odorless, and low water-soluble compound** but shows good solubility in organic solvents, fats, and oils.It does not occur naturally.

Method of Preparation:-DDT is prepared by heating chlorobenzene with chloral in presence of conc. H_2SO_4.



Uses of DDT:-

Between the 1950s and the 1980s, DDT was widely used in the **agricultural industry** as an **insecticide.** The use of DDT to control diseases like typhus and malaria was not uncommon in the early 1940s.

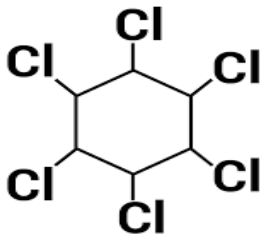
DDT acts upon the **sodium ion channels in the neurons of insects**, making them fire in a spontaneous manner. This causes the insects to undergo spasms and eventually die. However, certain mutations in insects can make them resistant to DDT. The primary application of this compound was, therefore, as an insecticide for the control of dangerous diseases like malaria. However, due to concerns over its negative impacts on the environment and human health, the use of this compound has been banned in several country.

Side Effects of DDT:-

- DDT is known to act as an endocrine disruptor. Therefore, exposure to this compound can result in interference with the endocrine system.
- This compound is also suspected to be a carcinogen to human beings. However, it can be noted that many studies suggest that this compound is not genotoxic.
- It can also be noted that DDT is classified as a moderately toxic substance by the US NTP (national toxicology program). Indirect exposure to this chemical compound is believed to be non-toxic to humans.
- DDT is also believed to interfere with the regular thyroid function in pregnant women.
- This compound has also been linked to a higher risk of developing autism in children.

BHC(Benzene Hexachloride): -

Structure

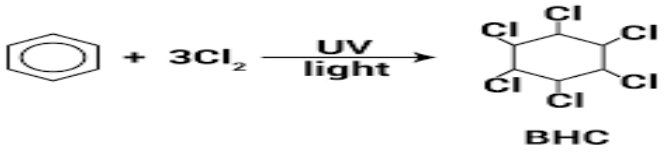


Its IUPAC name **is 1,2,3,4,5,6-hexachlorocyclohexane**.

Its molecular formula is **$C_6H_6Cl_6$**.

Properties:- BHC is a white,crystalline solid having no solubility in water and variable solubility in organic solvents. It is mostly soluble in halogenated solvents like chloroform, less soluble in esters and hydrocarbons and very less soluble in short chain alcohols.

Preparation of BHC:-It is prepared by chlorination of benzene in presence of ultraviolet light.



It occurs in various stereoisomeric forms but γ -isomer is most effective and also known as Lindane.

Uses of BHC:-

- It is used for pharmaceutical treatment of **lice and scabies** (or seven – year itch).
- It is also used as an **agricultural insecticide.** Although presently its agricultural use is regulated or banned in many countries. During 1950-2000, 600000 tons of BHC was produced globally for agricultural use.
- It is used in **medicinal shampoo or lotions.**
- It is used for second line treatments of various diseases.
- It is used for **seed treatment**.

Side Effects of Benzene Hexachloride: -

According to the World Health Organization, BHC or lindane is moderately acutely toxic. This is the reason its usage in agriculture has been regulated or banned. Its higher amount can affect the

nervous system and its production process is harmful for the environment.

- Large amounts of lindane can cause **headache, dizziness, convulsions or even death in rare cases.** It can affect the brain development of the child and can alter the thyroid hormone levels. At the level of 50 mg/m^3 and above, lindane may cause immediate death or can be very dangerous for life and health.
- It causes some adverse reactions which may cause **seizures, skin irritation, itching, rash, burning sensation**. These reactions of lindane make the skin very sensitive. It cannot be used for premature babies as it may cause severe neurotoxicity.
- **Lindane pollutes the environment**. It is termed as persistent organic pollutant or forever chemical. As it is a longlasting chemical in the environment. Its agricultural use is the primary reason for its presence in the environment. Through agriculture, it enters the food chains as well. The production process of lindane gives a large amount of toxic waste. According to studies, every ton of BHC production gives ten tons of toxic waste. BHC in soil can leach to groundwater and can reach to the atmosphere by volatilization and therefore can be deposited by rainfall.

Due to its agricultural applications a large quantity of lindane has been reported in the human body which is very dangerous for human health.

Saccharin: -

Structure:-

IUPAC Name:-

2H-1λ6,2-benzothiazol-1,1,3-trioneMolecular Formula:- $C_7H_5NO_3S$.

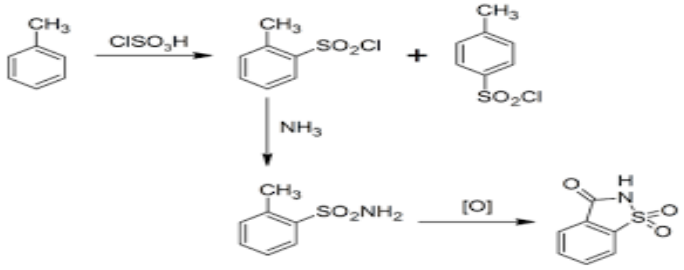
Properties:-

1. Saccharin is an **artificial sweetener with effectively no food energy**. It is about 300–400 times as sweet as sucrose but has a bitter or metallic aftertaste, especially at high concentrations.

2.Saccharin is **heat stable**. It is inert in nature so it does not react chemically with other food ingredients.

3.It is **water insoluble** but its **sodium salt is water soluble**.

Preparation:- It is prepared from toluene.



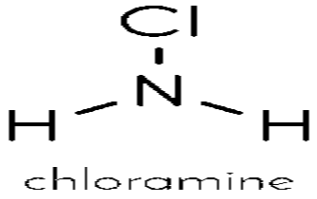
Uses:-

- Saccharin is used to sweeten products such as drinks, candies, cookies, and medicines.
- It is used in blended form with cyclamate or aspartame in diet carbonated soft drinks.
- It has no nutritional value it is safe to consume for persons with diabetes. It can help to reduced consumption of sugar.

Chloramine

It is derivative of ammonia. Chloramine also refers to a family of organic compounds with formulae R_2NCl and $RNCl_2$.

Structure:-



Its molecular formula **is NH_2Cl**

Properties:-

1.It is an inorganic compound. It is an unstable colorless liquid.

2.It is melting point is 66° C. It is generally handled as a dilute aqueous solution.

3.Pure chloramine decomposes violently above -40° C.

4.It is readily soluble in water and ether but less soluble in chloroform and carbon tetrachloride.

Preparation:- In dilute aqueous solution, chloramine is prepared by the **reaction of ammonia with sodium hypochlorite:**

NH_3 + NaOCl → NH_2Cl + NaOH.

Uses:-

- Chloramines (also known as secondary disinfection) are **disinfectants used to treat drinking water** and they: Are most commonly formed when ammonia is added to chlorine to treat drinking water. Provide longer-lasting disinfection as the water moves through pipes to consumers.
- It is used to improve odor and flavor of water.
- It can be used as a bleach and as oxidators.
- It is also used to resist biofouling water systems.

Important Questions of Module 01(Benzene and its Derivatives)

Questions carrying 2 marks.

1. Define Huckel's rule with examples.
2. Define aromaticity.
3. Give structure and uses of DDT.
4. Give structure and uses of BHC.
5. Give one synthetic evidence in support of structure of benzene.
6. Explain why pyridine is aromatic?
7. What is mixed acids?
8. Convert nitrobenzene to 1,3,5- tri bromo benzene.
9. What is Birch reduction reaction?
10. What is molecular orbital structure of benzene?
11. Explain Halogenation of benzene and its derivatives.
12. What is the effect of ortho and para directing groups on orientation?
13. What is the effect of meta directing groups on reactivity of benzene and its derivatives?
14. Write a note on

(a) Friedel craft Alkylation (b) Friedel Craft Acylation

Questions carrying for 5 or 10 marks.

1. Discuss the general mechanism and orientation of aromatic electrophilic substitution reaction.
2. Write in detail about reactivity, orientation and limitation of Friedel-craft Alkylation.
3. Write analytical, synthetic evidence in favors of structure of benzene.
4. Discuss mechanism of nitration of benzene.
5. Discuss the directive effect of substituents on electrophilic substitution in monosubstituted benzene.
6. Elaborate on various electrophilic substitution in benzene by giving the detailed mechanism of any one. Discuss in detail the effect of substituents on reactivity of these reactions.
7. Explain why nitrobenzene when nitrated further gives m-dinitrobenzene.
8. Discuss mechanism of Friedel Craft alkylation and its limitations.