Chapter: 16
Hydrocarbons

Q1. What are Hydrocarbons? How are they classified?

Hydrocarbons: Compounds containing carbon and Hydrogen only are called Hydrocarbons.

Catenation: Self-linking ability of element to form long chains. eg C–C–C–C– unlimited

Hydrocarbons

- **Open Chain**
  - **Saturated** H·C → Alkanes, eg: CH_4 methane
  - **Unsaturated** H·C
    - → Alkenes, eg: $CH_2=CH_2$ ethene
    - → Alkynes, $CH \equiv CH$ ethyne
- **Closed Chain**
  - **Alicyclic** H·C → eg:  Cyclohexane
  - **Aromatic** H·C → eg:  benzene

Open chain H·C / Aliphatic / Acyclic

Hydrocarbon in which C-atom are attached to each other in form of open chains.

TYPES:

- Saturated H·C
- Unsaturated H·C

Saturated H·C

Definition

H·C in which there is all single bond b/w C-atom.

Hybridization

All Carbons are sp^3

Type of Reaction

Undergo Substitution rxn

Example

1. CH_4 Methane
2. CH_3-CH_3 Ethane
3. $CH_3-CH_2-CH_3$ propane

UnSaturated H·C

Definition

H·C in which there is $C=C$ or $C\equiv C$ bond b/w C-atom.

Hybridization

$C=C$ sp^2 $C\equiv C$ sp

Type of Reaction

Undergo addition rxn

Example

1. $CH_2=CH_2$ ethene
2. $CH\equiv CH$ ethyne
3. $CH_2=CH-CH_3$ propene

Trick for Hybridization:

Group	Hybridization
1.	S
2.	sp
3.	sp^2
4.	sp^3

* $CH_2=CH_2$ = & ≡ counted as 1 Grp.
* lone pair is counted as 1 Grp.

Another trick for sp^3 Hybridization

eg: CH_4

→ Valency of central atom + attached atom

→ 4 + 1(4) ⇒ 8

→ Divide by 2 (2÷8) = 4 (sp^3)

Closed chain H·C

/cyclic / Ring

Hydrocarbons in which C-atom are attached with each other to form ring.

Types: /non-aromatic

Alicyclic H·C

Definition

Close chain H·C without benzene ring

Alternative Name

Non-benzoid

Huckel Rule

Do not obey

Example

- cyclopropane
- Cyclobutane
- Cyclo-pentane
- Cyclo-hexane

Aromatic H·C

Definition

Close chain H·C containing atleast one benzene ring.

Alternative Name

Benzoid

Huckel Rule

Obey Huckel rule

Example

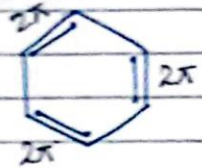
- benzene
- tolene
- Naphthalene
- Anthracene

Huckel Rule:

$4n + 2 = \pi e^-$

$n \rightarrow 1, 2, 3 \cdots$ (whole digit)

Q. Why benzene is aromatic?

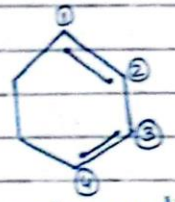


$4n + 2 = 6\pi$

$4n = 6 - 2$

$4n = 4$

$n = 1$ Obey huckle rule



1,3 cyclohexadiene

$4n + 2 = \pi e^-$

$4n + 2 = 4$

$4n = 4 - 2$

$\frac{4n}{4} = \frac{2}{4}$

$n = 0.5$ · does not obey

· Non-aromatic

Q. Why benzene is aromatic Hydrocarbon?

Benzene is an aromatic Hydrocarbon because it obey **Huckel Rule**. Originally, benzene was considered aromatic because of its smell. It has an aromatic odour. Huckel rule states that, a molecule is aromatic if it is cyclic, conjugated and has $(4n+2)\pi$ electrons.

Calculation:

$4n + 2 = \pi e^-$

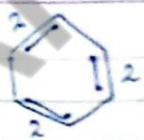
$4n + 2 = 6\pi e^-$

$4n = 6 - 2$

$4n = 4$

$n = 1$

· it obeys Huckel Rule.



$2+2+2 = 6\pi e^-$

Alkane	Alkenes	Alkynes
Parrafins (inert)	Olefins	
↳ C – C	↳ C = C	↳ C ≡ C
↳ Saturated	↳ Unsaturated	↳ Unsaturated
↳ Substitution rxn	↳ Addition rxn	↳ Addition rxn
↳ $C_n H_{2n+2}$	↳ $C_n H_{2n}$	↳ $C_n H_{2n-2}$
↳ Hexane	↳ Hexene	↳ hexyne
$C_6 H_{2(6)+2}$	$C_6 H_{12}$	$C_6 H_{10}$
$C_6 H_{14}$		

Homologous Series:-

Series of compound in which each member differ by $-CH_2$ group.

Structur

Ethane — Ethyne — Ethene

Propane — propene — propyne

butane — Cyclo-hexane

Alkyl Group (-R):-

When one H is removed from any alkane group form is called alkyl group / alkyl radical. $-R$ $C_n H_{2n+1}$

Rule: Replace ane → yl

Homologous Series of alkyl grp

Name	M.F	St. formula	Abbreviation
Methyl	$-CH_3$	$-\overset{H}{\underset{H}{\overset{|}{\underset{|}{C}}}}-H$	Me
Ethyl	$-C_2H_5$	$-\overset{H}{\underset{H}{\overset{|}{\underset{|}{C}}}}-\overset{H}{\underset{H}{\overset{|}{\underset{|}{C}}}}-H$	Et
n-propyl	$-C_3H_7$		n-Pr
n-butyl	$-C_4H_9$		n-bu

Important alkyl groups :-

n-propane
$CH_3-CH_2-CH_3$

Terminal (alkane) — Middle (alkane)

$-CH_2-CH_2-CH_3$ → n-propyl → 1° / primary propyl
C-atom attached to 1 C-atom

$CH_3-CH-CH_3$ → iso-propyl → 2°/sec propyl
Carbon-atom attached to 2-carbon atoms

n- butane
$CH_3-CH_2-CH_2-CH_3$

$-CH_2-CH_2-CH_2-CH_3$ → n- butyl → 1° Carbon

$CH_3-CH(CH_3)-CH_2-CH_3$ → iso-butyl → 2°/sec-butyl

iso - butane
$CH_3-CH(CH_3)-CH_3$

$-CH_2-CH(CH_3)-CH_3$ → iso-butyl
When 1 chain is on 2nd C-

$CH_3-C(CH_3)_2-CH_3$ → When C is attached to 4 chains → Neo-butyl / Ter-butyl

$CH_2=CH-$
Vinyl group (CH removed from ethene)

Common Names of alkanes / Paraffins

① CH_4 Marsh gas (found in marshes)

② $CH_3-\overset{2}{C}H(CH_3)-CH_3$ iso-butane

③ $CH_3-\overset{2}{C}H(CH_3)-CH_2-CH_3$ iso-pentane

④ $CH_3-C(CH_3)_2-CH_3$ neo-pentane

IUPAC Naming : 19 q

International union of pure & applied chemistry.

1. $CH_3-CH_2-CH_2-CH_2-CH_3$
n- pentane

Tips → Only use in alkane when there is no branch & straight chain.

2. $CH_3-CH_2-CH_2-CH_2-CH(CH_3)$
n-hexane

Tips → C - which can be written in straight line is a part of long chain.
→ longest chain containg larger number of C-atoms is selected which can be straight, bend etc.

Quick Rules

* When one branch is on 2nd Carbon it is called iso
* When 2 branch is on 2nd Carbon it is called Neo.
* Primary → Carbon connected to 1 Carbon.
* Sec → Carbon connected To 2 Carbons.
* Tertiary → Carbon connected To 3C
* Branch should be from 2nd Carbon.
* The side which has more branches we will stat numbering C-atom from there.
* For more than one similar group we us Di, Tri, Tetra.
* group on same C, no will be repeated twice.

→ Steps to Name:

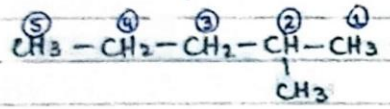
- Locate the longest Carbon chain.
- Name the parent chain.
- Figure out the ending.
- Number your C-atoms.
- Name the side groups.
- Put in alphabetical order.

→ Order:

* Remember !

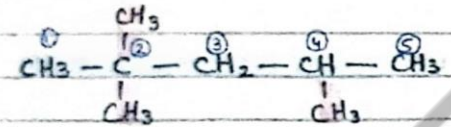
③ Number → group → parent chain → 2, 2

ex: 2 - Methyl pentane → 2-Methyl → 2-Methyl

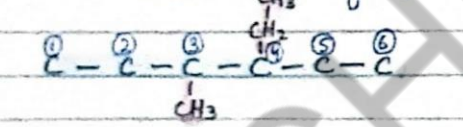


Tip → start numbering from that side which has more branches.

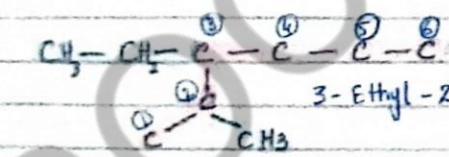
④ More than one same branches



2,2,4-Trimethyl pentane

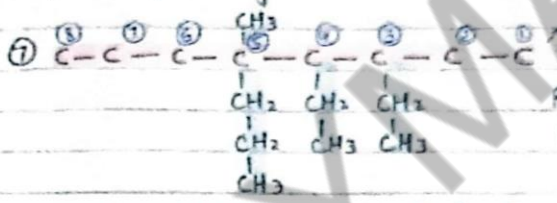
⑤ 

3-Ethyl-4-Methyl hexane

⑥ 

3-Ethyl-2-methyl hexane

Tip → Prefer long chain with more substituents

⑦ 

longest chain

R = 3+4+5 = 12 ✔

L = 4+5+6 = 15

3,4-DiEthyl-5-methyl-5-n propyl octane

Physical Properties of Alkane

① $C_1 - C_4$ Colourless, odourless gases

$C_5 - C_{17}$ Colourless, odourless liquid

C_{18} .... Solid (waxy solid)

② Alkanes are non-polar due to electronegativity difference.

③ Soluble in non-polar Solvents.

④ M.P & B.P increases with increase in no. of Carbon atoms.

⑤ Straight chain has more B.P as compared to branch chain.

⑥ M.P, B.P & density $\propto$ Carbon

Solubility $\propto \frac{1}{\text{C-atom}}$

⑦ B.P increase by adding CH_2 group $\Rightarrow$ 20-30°C

* n-chain has high boiling point due to strong LDF & surface area whereas	iso-chain has weak forces so have low boiling point.

Isomerism in alkane :-

The compounds which have same molecular formula but different structural formula are called isomers. This phenomenon is known as isomerism.

Note: Methane, Ethane, propane has no isomers bcz they have only 1 possible structure.

Isomers of butane: C_4H_{10}

① $CH_3 - CH_2 - CH_2 - CH_3$ n-butane

② $CH_3 - CH(CH_3) - CH_3$ iso-butane (C.N)
2-Methyl propane (IUPAC)

Isomers of Pentane: C_5H_{12}

① $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$ n-pentane

② $CH_3 - CH(CH_3) - CH_2 - CH_3$ iso-pentane (C.N)
2-Methyl butane (IUPAC)

③ $CH_3 - C(CH_3)_2 - CH_3$ Neo pentane (C.N)
2,2-Dimethyl propane (IUP)

Relative stability of alkane

Branch chain alkane are more stable than straight chain.

eg: 2-Methyl propane is more stable than n-butane.

Reactivity of alkane

↓

Parrafin

↙ ↘

Parum (little) Affin (reactivity / affinity)

Alkane

↳ do not react with

Acid, base, oxidizing agent, reducing agent but on suitable condition they react and give

(i) Thermal & Catalytic reaction

(ii) Substitution rxn

↳ Why alkanes are less reactive?

Alkanes are parrafins meaning less reactive bcz

- They have sigma bonds which is very strong as electrons are tightly held and it requires large energy To break.
- They are non-polar due To less electronegativity difference between C-H.
- They have equal sharing of e^- making it non-polar.

① Inertness of sigma bond

linear overlap
sigma bond

② Non-polar bond

C-C
2.5 - 2.5 = 0
C-H
2.5 - 2.1 = 0.4

↳ diff of electro-negativity is small but under suitable condition two rxns are possible 3

(1) Thermal & Catalytic rxn

(2) Substitution rxn

"SLO-BASED QUESTIONS"

1. Why alkanes are less reactive?

Alkane (paraffins) are less reactive, this is bcz of the inertness of the sigma bond present b/w them.

- Alkanes are non-polar in nature due to less electronegativity diff b/w C-H bond and they have = sharing of electrons as well.

eg: C = 2.5, H = 2.1 C-C = 2.5 - 2.5 = 0

C-H = 2.5 - 2.1 = 0.4

2. Why alkanes are called paraffins?

The term paraffin means little affinity. Basically alkanes are stable bcz of their inertness, they are called so bcz bcz they have lesser affinity towards general reagents. It means that they do not react with acid, base, oxidizing & reducing agents but only on suitable condition they react.

3. Why branch chain alkanes are more stable?

Branching reduces the molecular surface area and so leads to a lowering of energy and hence increases stability.

eg: 2-Methyl propane is more stable than n-butane. Also, it's difficult to break the substituent as it contains sigma so we could say that branched chain alkanes are less reactive but more stable.

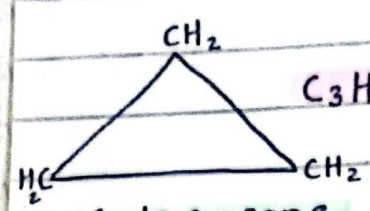
4. Why branched chain have lower B.P than Linear chain?

The boiling point of branched chain alkanes are lower than linear chain. This is bcz of L.D.F (weak) present in the branched chains of alkanes.

The surface area would be less & therefore they would have lower B.P. Linear chains have higher melting/boiling point due To better stacking and surface area contact.

→ Nomenclature of Cycloalkane:

- We use prefix cyclo
- General formula C_nH_{2n}
- The rest of the rules are same as that of alkane



C_3H_6

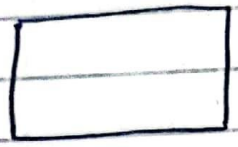
Cyclopropane

$CH_3-CH_2-CH_3$

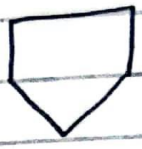
C_3H_8

propane

→ In cycloalkane there is always 2H less than straight chain alkane.

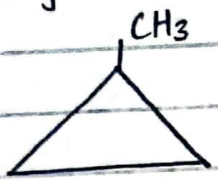


Cyclobutane

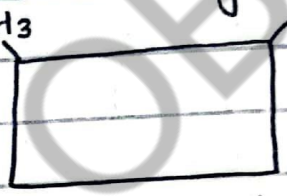


Cyclopentane

Cyclohexane



1-Methyl cyclopropane



1,2-Dimethyl cyclobutane

↳ Physical Properties:-

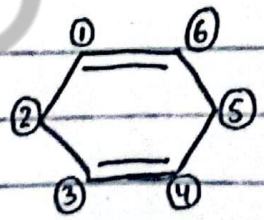
* London Dispersion forces] same as alkane
* M.P & B.P = Low

↳ Reactivity:-

Cycloalkane is also less reactive due To

(i) Sigma bond

(ii) Non-Polar bond



Cyclo 1,3-hexadiene

or Cyclohexa-1,3-diene

BOND FISSION:

↳ Homolytic fission

When a chemical bond is broken in such a way that both of bonded atoms aquire equal electrons such fission is called homolytic.

General Eq: $A-B \xrightarrow{h\nu} A^{\cdot} + B^{\cdot}$

Example: $Cl-Cl \xrightarrow{h\nu} Cl^{\cdot} + Cl^{\cdot}$

↳ Hetrolytic fission

When a chemical bond is broken in such a way that one of the bonded atom aquire both e^-s. such fission is heterolytic.

General Eq: $A-B \longrightarrow A^- + B^+$

Example: $H-Cl \longrightarrow Cl^- + H^+$

Q. What is a free radical?

It has

↳ odd no. of e^-

↳ Neutral charge

↳ Highly reactive

↳ Chain rxn

↳ Radical Substitution Reaction:

Halogenation: (X) (F, Cl, Br, I)

Replacement of Hydrogen atom by Halogen is called Halogenation.

↳ Condition for Halogenation

Halogenation of alkane takes place in presence of
↳ Sunlight
↳ UV radiation
↳ High Temp

↳ Reactivity of Halogen:

$$F_2 > Cl_2 > Br_2 > I_2$$

- For Halogenation Cl_2 and Br_2 are used.
- F_2 and I_2 are not used.
- In case of F_2 reaction take place violently and in case of I_2 reaction is slow and reversible.

Cl ⟶ Chlorination
Br ⟶ Bromination
> Halogenation

Steps:

1. Initiation ⟶ formation of free radical
2. Propagation ⟶ both side radical (R & P)
3. Termination ⟶ reactant radical

Reaction:

$$CH_4 + Br_2 \xrightarrow{hr} CH_3Br + HBr$$
$$CH_3Br + Br_2 \xrightarrow{hr} CH_2Br_2 + HBr$$
$$CH_2Br_2 + Br_2 \xrightarrow{hr} CHBr_3 + HBr$$
$$CHBr_3 + Br_2 \xrightarrow{hr} CBr_4 + HBr$$

Overall reaction:

$$CH_4 + 4Br_2 \xrightarrow{hr} CBr_4 + 4HBr$$

Mechanism:

Step: 1 Initiation (generation of free radical)

$$Br-Br \xrightarrow[\text{diffused}]{hr} Br^{\cdot} + Br^{\cdot}$$

Step: 2 Propagation

$$CH_3-H + Br^{\cdot} \xrightarrow{hr} CH_3^{\cdot} + HBr$$
$$CH_3^{\cdot} + Br-Br \xrightarrow{hr} CH_3Br + Br^{\cdot}$$
$$CH_3Br + Br^{\cdot} \xrightarrow{hr} CH_2^{\cdot}Br + HBr$$
$$CH_2^{\cdot}Br + Br-Br \xrightarrow{hr} CH_2Br_2 + Br^{\cdot}$$
$$CH_2Br_2 + Br^{\cdot} \xrightarrow{hr} CH^{\cdot}Br_2 + HBr$$
$$CHBr_2^{\cdot} + Br-Br \xrightarrow{hr} CHBr_3 + Br^{\cdot}$$
$$CHBr_3 + Br^{\cdot} \xrightarrow{hr} CBr_3^{\cdot} + HBr$$
$$CBr_3^{\cdot} + Br-Br \xrightarrow{hr} CBr_4 + Br^{\cdot}$$

→ Whenever Br—Br reacts, it is added to other.
→ Whenever $Br^{\cdot}$ reacts, it takes away H & form HBr making other comp free radical.
→ Use $Br^{\cdot}$ and Br—Br alternatively.

Step: 3 Termination

$$CH_3^{\cdot} + Br^{\cdot} \xrightarrow{hr} CH_3Br$$
$$CH_3^{\cdot} + CH_3^{\cdot} \xrightarrow{hr} CH_3-CH_3$$
$$Br^{\cdot} + Br^{\cdot} \xrightarrow{hr} Br-Br$$

* both Reactan should be free radicals

Q How many products are possible?

$CH_4 + Br_2 \xrightarrow{hr} CH_3Br + CH_2Br_2 + CHBr_3 + CBr_4 + CH_3-CH_3$

Oxidation	Reduction
→ Addition of Oxygen ie more C O bond.	→ Removal of Oxygen ie less of CO bond
→ Removal of H ie Less CH	→ Addition of H ie more CH
→ Loss of electron	→ Gain of electron
→ Increase in O.S	→ Decrease in OS
$Cu^{\circ} \longrightarrow Cu^{+2} + 2\bar{e}$	$Zn^{+2} + 2\bar{e} \longrightarrow Zn^{\circ}$

Isomerism

Definition:

Different compounds having same Molecular formula but different structural formula & Physical properties are called isomers. This phenomenon is known as isomerism.

↳ Methane, ethane, propane has no isomers.
↳ Butane has Two isomers
↳ Pentane has three isomers.
↳ Hexane has five isomers.

Note:

As No. of C-atom increases, no. of

Types:-

1) STRUCTURAL ISOMERISM:

Different compounds having same M.F but diff structures are called structural isomers & Phenomenon is called structural isomerism.

Sub-types:

i- Chain isomerism:

Diff comp having same M.F but diff C-chain.

eg: $CH_3-CH_2-CH_2-CH_3$ n-butane

$CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_3$ Iso-butane or 2-Methyl propane

ii- Position isomerism:

Same M.F but diff position of same functional group.

eg: (a) $CH_2=CH-CH_2-CH_3$ 1-butene

$CH_3-CH=CH-CH_3$ 2-butene

(b) $\underset{\underset{Cl}{|}}{CH_2}-CH_2-CH_3$ 1-Chloropropane

$CH_3-\underset{\underset{Cl}{|}}{CH}-CH_3$ 2-Chloropropane

iii- functional group isomerism:

Same M.F but diff functional group.

eg: (a) C_2H_6O : CH_3-O-CH_3 Dimethyl Ether; CH_3-CH_2-OH Ethyl Alcohol

(b) C_3H_6O : $CH_3-CH_2-\overset{O}{\overset{\|}{C}}-H$ propanal; $CH_3-\overset{O}{\overset{\|}{C}}-CH_3$ propanone

4. Metamerism:

Same M.F but unequal distribution of C-atom on either side of fundional group.

eg: (a) $C_4H_{10}O$: $CH_3-CH_2-O-CH_2-CH_3$ Diethyl Ether; $CH_3-O-CH_2-CH_2-CH_3$ Methyl-n-propyl Ether

(b) $CH_3-CH_2-NH-CH_2-CH_3$
Diethyl amine

$CH_3-NH-CH_2-CH_2-CH_3$
Methyl-n-propyl amine

5. Tautomerism:

Type of isomerism in which 1 isomer is converted in other isomer due to migration of H ion are called tautomer & Phenomenon is called Tautomerism.

$R-\underset{NH_2}{\overset{H}{C}}-COOH \rightleftharpoons R-\underset{NH_3}{\overset{H}{C}}-COO^-$

Zwitter ion (Internal Salt)

$CH_3-\overset{O}{\overset{\|}{C}}-CH_2-\overset{O}{\overset{\|}{C}}-OC_2H_5 \rightleftharpoons CH_3-\overset{OH}{\overset{|}{C}}=CH-\overset{O}{\overset{\|}{C}}-OC_2H_5$

keto form — enol form

en → double bond
ol → alcohol

2) Sterio-Isomerism: (3D)

Different compounds having same Molecular formula but diff arrangement or orientation of atoms or groups in the 3D space are called sterio isomers. This phenomenon is known as sterio-isomerism.

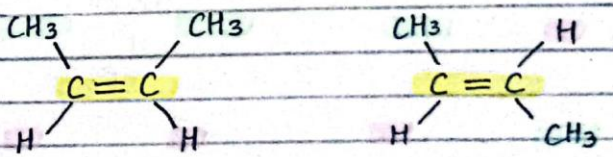
Sub-types:

1. Geometrical Isomerism:

Same M.F but diff position of identical group in space.

Cis form: When two identical groups lie on same side of = bond.

Trans form: When two identical groups lie on opposite side of = bond.



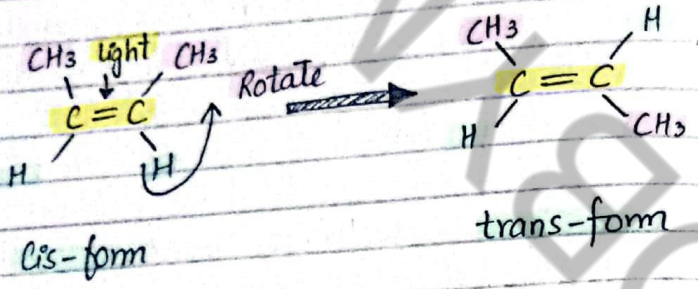
Cis-2-butene — Unstable $\mu \neq 0$

trans-2-butene — Stable $\mu = 0$

Q. Why dipole moment of trans is zero?

Bcz two bulky grps lie on opposite side of = bond so steric repulsion is less & dipole moment = 0

* They are interconvertible into each other in presence of light / high temp bcz of π bond breaking & C - will retake.

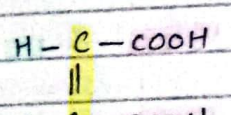


Cis-form trans-form

Conditions for geometrical isomerism:

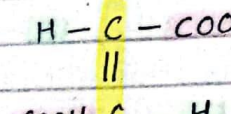
(1) Two groups attach with same carbon must be different.

(2) C-C bond should be not rotate about its axis.



Maleic acid

Cis-2-butene-1,4-dioic acid



fumaric Acid

Trans-2-butene-1,4-dioic acid

Q. Why 1-butene does not form cis and trans iso-merism?

In the case of 1-butene, its structure is $CH_2=CH-CH_2-CH_3$. 1-butene will not have cis-trans isomerism the reason for this is CH_2 & CH_3 are not identical groups.

Reasons:

1. Position of double bond:

In 1-butene, the double bond is located b/w the 1st & 2nd C-atoms in the chain (1-position)

2. Lack of different groups:

for geometric isomerism to occur, each Carbon in the double bond must have two diff groups attached. In 1-butene, the first Carbon of the double bond has two Hydrogen atoms attached ($H_2C=$), and the second Carbon is connected to a Hydrogen atom & an ethyl group(CH-).

Conclusion:

Since the 1st C-atom in the double bond has two identical Hydrgen atoms attached to it, it cannot form cis & trans isomers.

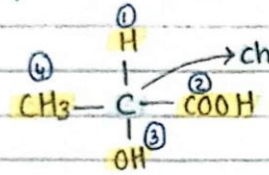
Optical Isomerism:

Condition:

1- atom should have chiral Carbon.
2- Should not have plane of Symmetry.

1) Chiral center / chiral Carbon / Asymmetric

Carbon atom which is bonded with 4 different groups or atom is called chiral carbon.



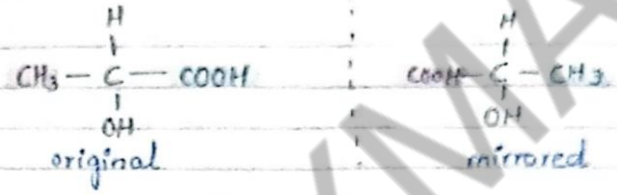
2) Plane of Symmetry:

Plane which divides an object into symmetrical halves is called plane of symmetry.

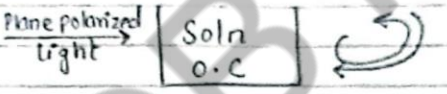
Example: A person or hat has plane of Sym.
A person hand & gloves lack plane of Sym.

Conditions for chiral molecule:

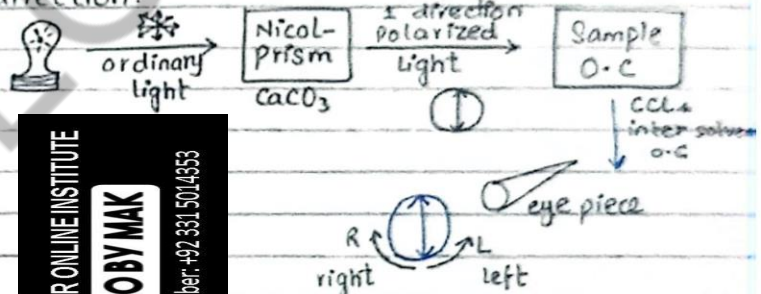
Chiral molecule has atleast an asymmetric Carbon and does not have plane of symmetry and are not superimposible on their mirror image.



3) Optical activity:



Solution of some O.C have ability to rotate plane polarized light in opposite direction.



Dextro-rotatory (+) isomer clockwise

Levorotatory (−) isomer anticlockwise

Optical isomerism:

Optically active compound can exist in 2 isomeric forms which rotate plane polarized light in opposite direction.

→ Dextrorotatory & Levorotatory are called Enantiomer.

→ Alkene

Nomenclature:-

① $\overset{1}{C}H_3 - \overset{2}{C} = \overset{3}{C}H_2$

1-propene or prop-1-ene

② $\overset{1}{C}H - \overset{2}{C}H_2 - \overset{3}{C}H \equiv \overset{4}{C}H - \overset{5}{C}H_2 - \overset{6}{C}H_3$

3-Hexene

Z-form → When 4 diff group

(small) F, By (small)

C = C

(large) Cl, I (large)

E-form → Trans form

(small) F, I (large)

C = C

(large) Cl, Br (small)

③ $\overset{1}{C}H_2 = \overset{2}{C}H - \overset{3}{C}H = \overset{4}{C}H - \overset{5}{C}H_3$ 2 + 2 = 6

1,3-pentadiene or 1+3 = 4

penta-1,3-diene or

1,3-Dipentene

④ $\overset{1}{C}H_2 = \overset{2}{C} = \overset{3}{C} \equiv \overset{4}{C}H - \overset{5}{C}H_2 - \overset{6}{C}H_3$

1,2,3-Hexatriene or

Hexa-1,2,3-triene

⑤ $\overset{1}{C}H_3 - \overset{2}{\underset{CH_3}{\underset{|}{C}}} - \overset{3}{C}H \equiv \overset{4}{C}H - \overset{5}{\underset{CH_3}{\underset{|}{C}}} - \overset{6}{C}H_3$

2,2,5,5-Tetramethyl-3-hexene

⑥ 3-Methyl-1,3-pentadiene

$\overset{1}{C}H_2 = \overset{2}{C}H - \overset{3}{\underset{CH_3}{\underset{|}{C}}} \equiv \overset{4}{C}H - \overset{5}{C}H_3$

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eaction with Primary alcohol:

$$R-\overset{\beta}{CH_2}-\overset{\alpha}{CH_2}(OH) \xrightarrow[340-450^\circ C]{Al_2O_3} R-CH=CH_2 + H_2O$$

Primary alcohol
i - Alcohol

Pri - Carbon
C bonded to 1 C.

$$R-\overset{\beta}{CH_2}-\overset{\alpha}{CH_2}(OH) \xrightarrow[140-170^\circ C]{H_2SO_4\ 75\%} R-CH=CH_2 + H_2O$$

i - alcohol

Sec - Carbon
C bonded to 2 C.

ter - Carbon
C bonded to 3 C.

Reaction with Secondary Alcohol:

$$R-\overset{\beta}{CH_2}-\overset{\alpha}{CH}(OH)-\overset{\beta}{CH_3} \xrightarrow[100^\circ C]{H_2SO_4\ 60\%} R-CH=CH-CH_3 + H_2O$$

2° - Alcohal

Reaction with tertiary Alcohol:

$$R-\overset{CH_3\ \beta}{\overset{|}{\overset{\alpha}{C}}}(OH)-\overset{\beta}{CH_3} \xrightarrow[85^\circ C]{H_2SO_4\ 20\%} R-\overset{CH_3}{\overset{|}{C}}=CH_2 + H_2O$$

3° - Alcohol

Order of Reactivity:

3° - Alcohol > 2° - alcohol > 1° alcohol

85°C 100°C 140-170°C

due to stability of carbo-cation, there are 3 ranches to support C therefore tertiary alcohol more reactive.

2. DehydroHalogenation:

" Removal of H & X from alkyl halide "

* MdCat *

Reagent → Participate in Rxn	Alcoholic KOH ⇒ Elimination
	Aqueous KOH ⇒ Substitution

General Reaction:

$$R-\overset{\beta}{CH_2}-\overset{\alpha}{\underset{|}{CH_2}}(X) + KOH \xrightarrow[100^\circ C]{alcohol} R-CH=CH_2 + KX + H_2O$$

Examples:

1. $CH_3-\overset{\beta}{CH_2}-\overset{\alpha}{\underset{|}{CH_2}}(Br) + KOH \xrightarrow[100^\circ C]{alcohol} CH_2=CH_2 + KBr + H_2O$

i - R-X

2. $\overset{\beta}{CH_3}-\overset{\alpha}{\underset{|}{CH}}(Br)-\overset{\beta}{CH_2}-CH_3 + KOH \xrightarrow[100^\circ C]{alcohol} \overset{\text{2-butene}}{CH_3-CH=CH-CH_3} + KBr + H_2O$

SLO Question

1. How will you prepare alkene from dehydro-halogenation?
2. Write 2 - methods for preparation of alkene?
3. How will you obtain 1-butene from
   a. alcohol
   b. alkyl Halide

Relative stability:

1. **Degree of Substitution**
   alkyl group ∝ stability

2. **Highly alkalated**
   Highly alkalated alkene are more stable e.g
   Tetra > tri > Di > Monosubstituted

* **Branch increase B.P increase**
   Branched structure is more stable bcz its B.P will be high and it will be difficult to break the bond.

2. **Stereochemistry**
   Trans alkene is more stable than Cis alkene due to reduced steric hindrance (bulky groups are in opposite direction)

3. **Conjugation** (alternate C-C=C-C=C) ← Conjugated
   Conjugated alkene are more stable than isolated alkene.
   (C=C-C-C=C) → Isolated

→ Delocalization of π bond

$\overset{1}{C}=\overset{2}{C}-\overset{3}{C}=\overset{4}{C}-\overset{5}{C}$ more stable

$\overset{1}{C}=\overset{2}{C}-\overset{3}{C}-\overset{4}{C}=\overset{5}{C}$ isolated

Structure of alkene:-

$CH_2 = CH_2$

- Sp^2 hybridization
- 1 sigma & 1 π-bond
- 1s & 2p orbital overlap

MCQ

Alkane C-C 1.54 Å

Alkene $CH_2=CH_2$ 1.34 Å

C=C → e⁻ density ↑

Preparation of alkene

Saytzeff's Rule: (Elimination)
β Carbon that has less H, H will be removed & = bond will be formed on that Carbon.

1. Dehydration of Alcohol:-

"Removal from alcohol of H_2O"

Dehydrating agents:

- Al_2O_3 Alumina
- H_3PO_4 Phosphoric acid
- P_4O_{10}
- P_2Os
- H_2SO_4 → best dehydrating agent for alcohol bcz it can tell reactivity order of alcohol.

α-Carbon C-atom with OH
β-Carbon C-atom bonded to α-Carbon

4. Why alkene are more reactive than alkane?

C=C $\overset{1}{1}\overset{\sigma}{\pi}$	C-C
More diffused bond (more e^- density)	less diffused bond
π-bond weak	σ-bond strong
less amount of Energy is required to break bond.	More amount of Energy is required to break bond.

Electrophilic addition Reaction of alkene:-

Electropile
Electron loving
E^+ → cation
→ Electron deficient
→ $\underline{B}F_3$ B^+

Nucleophile
Nucleus loving
Nu^- → Anion
→ Electron rich
→ Mostly bases OH^-

(preparation of alkane)

1- Hydrogenation:- (Addition of H_2)

"Addition of Hydrogen molecule H_2 in the molecule of alkene"

$$CH_2=CH_2 + H_2 \xrightarrow[200-300^\circ C]{Ni} CH_3-CH_3$$

Ethene → Ethane

MdCat

↳ It is always an Endothermic rxn (Bond breaking)
↳ Veg ghee prepared from veg oil
1 bond releases -120 KJ/mol

Step: 2

$CH_3-CH_2^{\oplus} + X^{\ominus} \longrightarrow CH_3-CH_2-\overset{X}{|}$

Electrophile

Markownikov's Rule :- (For Addition Rxn)

$CH_3^3-CH^2=CH_2^1 + H^{+\delta}-Cl^{-\delta}$

Unsymmetrical alkene

1- propene

$CH_3-CH(Cl)-CH_2(H)$

2- Chloro propane

-δ will go towards = Carbon which has less H.

$CH_3^3-C^2(CH_3)=CH_2^1 + H^{+\delta}-Br^{-\delta} \longrightarrow CH_3^3-C^2(CH_3)(Br)-CH_3^1$

2 - methyl-1-propene

2-bromo-2-methyl propane

3. Hydration:

Addition of H_2O to alkene molecule is called hydration.

↳ Alkene does not dissolve in water so H_2SO_4 is added to dissolve it

Mechanism:

$CH_2=CH_2 + H^{+\delta}-HSO_4^{-\delta} \longrightarrow CH_3-CH_2-HSO_4$

Ethene — Conc. Catalyst — alkyl Hydrogen Sulphate (Intermediate)

$CH_3-CH_2-HSO_4 + H-OH \xrightarrow{100^\circ C} CH_3-CH_2-OH + H_2SO_4$

1° Alcohol (ethanol)

MCQs

Hydration of alkene produces alcohol.

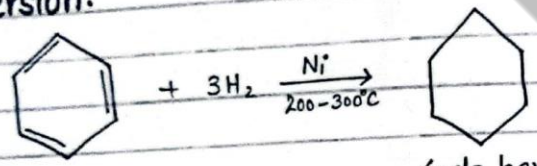
Overall Reaction:

$CH_2 = CH_2 + H-OH \xrightarrow[100^\circ C]{H_2SO_4} CH_3-CH_2-OH$

$CH_2=CH-CH_3 + \overset{+\delta}{H}-\overset{-\delta}{OH} \xrightarrow[100^\circ C]{H_2SO_4} CH_3-\underset{\underset{OH}{|}}{CH}-CH_3$

2-propanol
2-Hydroxy propane

Conversion:



Cyclo hexene
1,3,5-Cyclohexatriene

Cyclo hexane

$CH_3-CH_2-CH=CH_2 \longrightarrow$ butanol
butene

$CH_3-CH_2-CH=CH_2 + H_2O \longrightarrow CH_3-CH_2-\underset{\underset{OH}{|}}{CH}-CH_3$

4. Halogenation:- (Test for unsaturation)

"Addition of Halogen in the molecule"

↳ Alkane halogenation takes place in the presence of Sunlight.

↳ Alkene halogenation inert Solvent CCl_4.

↳ Halogenation of alkene produces vicinal dihalide.

$CH_2=CH_2 + Br_2 \xrightarrow[25^\circ C]{CCl_4} \underset{\underset{Br}{|}}{CH_2}-\underset{\underset{Br}{|}}{CH_2}$ Vicinal dihalide
ethene 1,2-Dibromo Ethane

$\overset{Br}{\underset{|}{C}}-\overset{Br}{\underset{|}{C}}-Br$ ⟶ Geminal (1 C has Two Halogens)

$CH_3-CH=CH_2 + Cl_2 \xrightarrow{CCl_4} CH_3-\underset{\underset{Br}{|}}{CH}-\underset{\underset{Br}{|}}{CH_2}$

Propene 1,2-Dichloropropane

↳ **Mechanism:**

* +δ always on left side Br.

Step: 1

$CH_2=CH_2 + \overset{+\delta}{Br}-\overset{-\delta}{Br} \longrightarrow CH_2-\overset{\oplus}{C}H_2$
Polarity induced
$:\ddot{Br}:$ (Carbocation)

* $Br^\ominus$ ⟶ Bromide ion
$Br^\oplus$ ⟶ Bromine ion

$\left[CH_2-CH_2 \text{ (Br}^\oplus\text{ bridge)}\right] + Br^\ominus$

Bromonium ion
or
intermediate

Step: 2

bond making inward

$CH_2-CH_2^\oplus + Br^\ominus \longrightarrow \underset{\underset{Br}{|}}{CH_2}-\underset{\underset{Br}{|}}{CH_2}$
Bromide ion
Vicinal dihalide

outward bond breaking

* If Br colour disapears, it means double bond is present. Start → brown End → colourless

* Saturated (single bond) → No change in colour

Conversion: 2-butene ⟶ 2,3-Dibromobutane

* Halogenation

$CH_3-CH=CH-CH_3 + \overset{+\delta}{Br}-\overset{-\delta}{Br} \longrightarrow CH_3-\underset{\underset{Br}{|}}{CH}-\underset{\underset{Br}{|}}{CH}-CH_3$

5. Halohydration:-

"Addition of hypohalous Acid (HOX) is called halohydration"

⇒ Water as solvent act as a reactant, it can be called as reagant.

generally,

(i) $X_2 + H\text{-}OH \longrightarrow HX + HOX$ (more reactive)
Hypohalous Acid

Q. How will you produce Halohydrin by using ethene?
Q. How will you produce chlorohydrine by using ethene?

$H\text{-}OH + Cl\text{-}Cl \longrightarrow HCl + HOCl$
hypochlorous Acid

Generally,

ii) $CH_2=CH_2 + \overset{-\delta\ +\delta}{HOX} \longrightarrow CH_2(OH)-CH_2(X)$ (halohydrin)
ethene

$CH_2=CH_2 + HOCl \longrightarrow CH_2(OH)-CH_2(Cl)$ (chlorohydrin)
ethene

General overall rxn:

$X_2 + CH_2=CH_2 + H_2O \longrightarrow CH_2(OH)-CH_2(X) + HX$

$Cl_2 + CH_2=CH_2 + H_2O \longrightarrow CH_2(OH)-CH_2(Cl) + HCl$

*Similarly bromohydrin, Iodohydrin etc

Conversion:

Propene ⟶ 1-chloro-2-Propanol

$CH_3-CH=CH_2 + HOCl \longrightarrow CH_3-CH(OH)-CH_2(Cl)$
propene — hypochlorous Acid — 1-chloro-2-propanol

Ethene ⟶ 2-chloro Ethanol

$CH_2=CH_2 + HOCl \longrightarrow CH_2(OH)-CH_2(Cl)$
ethene — 2-chloro Ethanol

6. Epoxidation:-

↳ Epoxidation of alkene produces epoxy alkane

↳ peroxy Acid ↳ Peroxy Acetic Acid, Peroxy Benzoic Acid

$CH_3-C(=O)-OH$
Acetic Acid

$CH_3-C(=O)-O-OH$
Peroxy Acetic Acid

C_6H_5-COOH
Benzoic Acid

$C_6H_5-C(=O)-O-OH$

$CH_2=CH_2 + CH_3-C(=O)-O-OH \xrightarrow{CHCl_3} CH_2-CH_2$ epoxide
Ethene — Peroxy Acetic acid — Cyclic ether

Epoxy ethane
$+ CH_3C(=O)-OH$
Acetic Acid

$CH_2=CH_2 + C_6H_5-\overset{O}{\overset{\|}{C}}-O-OH \xrightarrow{CHCl_3} CH_2-CH_2 + C_6H_5-\overset{O}{\overset{\|}{C}}-OH$ (epoxide O)

Conversion:

$CH_3-CH=CH_2 + CH_3COOOH \xrightarrow{CHCl_3} CH_3-CH-CH_2 + CH_3COOH$ (epoxide O)

$CH_3-CH=CH_2 + C_6H_5COOOH \xrightarrow{CHCl_3} CH_3-CH-CH_2 + C_6H_5COOH$ (epoxide O)

Q. How will you produce ethylene epoxid or ethylene oxide? (3)

$H_2C=CH_2 + 1/2\ O_2 \xrightarrow{Ag_2O} H_2C-CH_2$ (epoxide O)

ethylene epoxid or ethylene oxide

$H_3C-CH=CH_2 + 1/2\ O_2 \xrightarrow{Ag_2O} CH_3-CH-CH_2$ (epoxide O)

Propylene epoxid

1. Ozonolysis :-

"Addition of ozone which causes unsaturated compound to break"

↳ Ozonolysis of alkene produces carbonyl comp (aldehyde & ketone)

Test: Used To locate position of = bond in alkene.

Steps:

① Alkene + O_3 ⟶ Molozonide (unstable) $\xrightarrow{②\ \text{rearrangement}}$ ozonide (Mild stable)

③ Ozonide + H_2O (Boiling water) $\xrightarrow[100°C]{\text{reduction } Zn}$ Carbonyl comp (Aldehyde & ketone) + H_2O_2 by-Product

④ $H_2O_2 + Zn \longrightarrow ZnO + H_2O$

Example: Q. Convert alkene into formaldehyde by ozonolysis

(a) $CH_2=CH_2 + O_3 \longrightarrow$ (molozonide ring: CH_2, CH_2, O, O, O)

Molozonide (unstable)

(ozonide ring: CH_2, CH_2, O, O, O) + $H_2O \xrightarrow[100°C]{Zn} CH_2=CH_2 + H_2O_2$

ozonide (mild stable)

or

$2\ H-\overset{O}{\overset{\|}{C}}-H + H_2O_2$ (Hydrogen Per oxide)

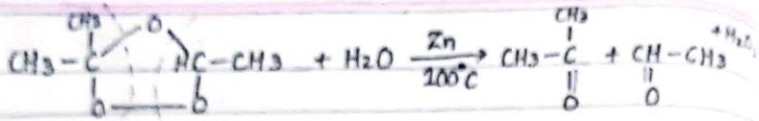
formaldehyde (Methanal)

$H_2O_2 + Zn \longrightarrow ZnO + H_2O$

Zinc oxide

(b) $CH_3-\overset{CH_3}{\overset{|}{C}}=CH-CH_3 + O_3 \longrightarrow CH_3-\overset{CH_3}{\overset{|}{C}}(O-O-O)-CH-CH_3$

Molozonide (Unstable)

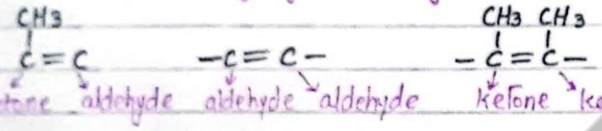


ozonide
(mild stable)

ketone (Propanone) | Aldehyde (Ethanal)
C·N ⇒ Acetone | Acetaldehyde

$H_2O_2 + Zn \longrightarrow ZnO + H_2O$

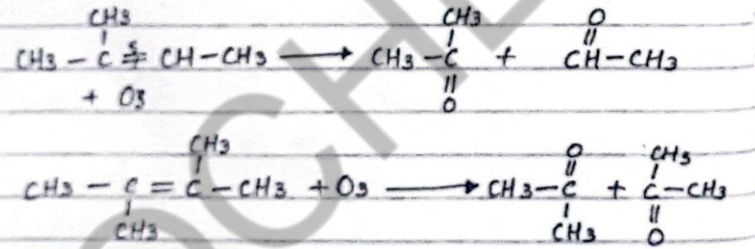
TRICK:
- Alkene in which (=) Carbon has branch they give ketone.
- Alkene in which double bonded Carbon has no branch they give aldehyde.

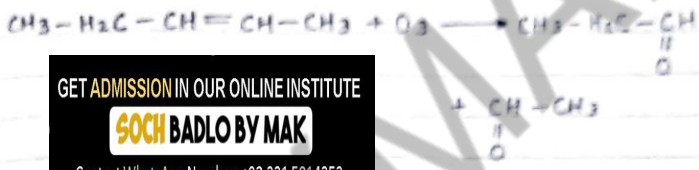


ketone aldehyde | aldehyde aldehyde | ketone ketone

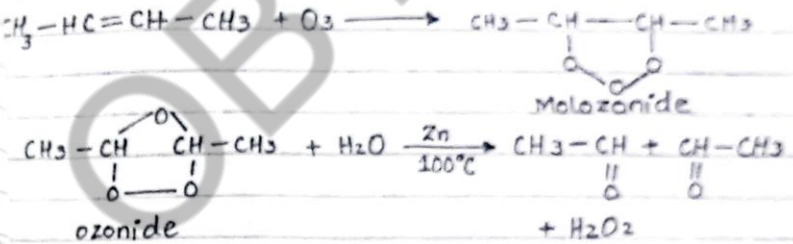
SHORT CUT FOR MCQ:
- add one oxygen on = bond.

$CH_2 = CH_2 + O_3 \longrightarrow CH_2O + CH_2O$





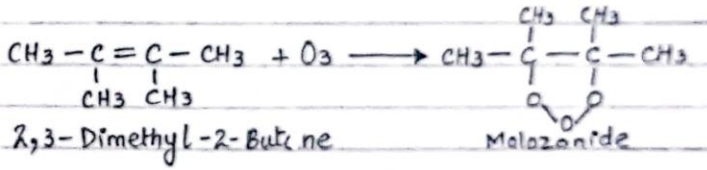
Q. How will you convert alkene into acetaldehyde?



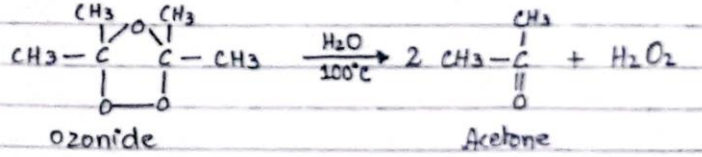
Molozonide
ozonide
+ H_2O_2

$H_2O_2 + Zn \longrightarrow ZnO + H_2O$

Q. How will you convert alkene into acetone?



2,3-Dimethyl-2-Butene
Molozonide



ozonide
Acetone

$H_2O_2 + Zn \longrightarrow ZnO + H_2O$

8. Polymerisation:-

"The process in which small molecules combine to give large molecule in the presence of heat and catalyst."

"Process in which small (called monomer) combine with each other & form large molecule called polymer is called polymerization"

Small Molecule (monomer) ⟶ large Molecule (Polymer)

Example:

$n\,CH_2 = CH_2 \xrightarrow[100\,atm]{(Pt)\ 400^\circ C,\ 0.1\%\ O_2} \left[CH_2 - CH_2\right]_n$

ethylene (ethene) → Polythene or Polyethylene

* More O_2 will cause combustion.

Other Catalyst:

* (Pt, Pd, $TiCl_4$, Ni)
* For high quality polyethene $Al(C_2H_5)_3$ aluminium triethyl & $TiCl_4$ (Titanium tetrachloride) is used as a catalyst.

Alkynes

Relative stability:-

Alkynes are more stable than alkene due to extra π bond therefore alkynes are less reactive than alkenes.

$C \overset{2\pi}{\underset{1\sigma}{\equiv}} C$ — Less reactive, More stable, ↑ e^- density

$C \overset{1\pi}{\underset{1\sigma}{=}} C$ — More reactive, less stable, ↓ e^- density

→ Order of reactivity: (dec order of reactivity)
Alkene > alkyne > alkane

→ Order of stability: (dec order of stability)
(σ) Alkane > alkyne (2π) > alkene (1π)

1- Hexyne — $\Delta H = 290$ KJ/mol ⟶ 2π
1- Hexene — $\Delta H = 126$ KJ/mol ⟶ 1π

Physical Properties of alkyne:-

1- They are non-polar insoluble in water but soluble in non-polar organic solvent. CCl_4, C_6H_6, tolene, alcohol, ether, Acetone, hexene etc

2- All alkynes are colourless & odourless except (acetylene) ethyne which has garlic like odour

3- Melting point & Boiling point, density increase with increase in no of carbon atom.

4- Increase in S-character causes increase in E·N of Carbon. (MdCat)

$C\equiv C$ > $C=C$ > $C-C$

Sp=50% polar Sp^2=33·3% Sp^3=25%

S-character ∝ Polarity

5. lower alkanes → Gases (C_2-C_4)
higher alkanes → Liquids (C_5-C_{12})
More higher alkanes → Solids ($C_{13}-C_n$)

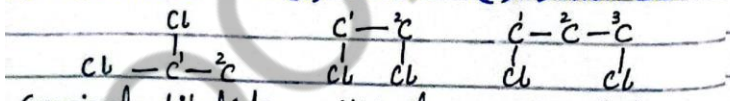
Preparation of alkynes by Elimination

1- Dehydrohalogenation:

"Removal of HX from the molecule"

Reagent = (i) Alcoholic KOH → Elimination
(ii) $NaNH_2$ + liq. NH_3 at 100-200°C / -33°C
(sodaamide)

A) Geminal (B) Vicinal (C) Dihalide



Geminal dihalide — Vicinal dihalide — Dihalide

(A) From Vicinal dihalide

i) $CH_3-\overset{\beta}{C}H(Br)-\overset{\alpha}{C}H(Br)-\overset{\beta}{C}H_3 + KOH \xrightarrow[100-200°C]{alc} CH_3-C(Br)=CH-CH_3 + KBr + H_2O$

2,3-Dibromo butane — 2-Bromo 2-Butyne

$CH_3-\overset{\beta}{C}(Br)-\overset{\alpha}{C}H-\overset{\beta}{C}H_3 + KOH \xrightarrow[100-200°C]{alc} CH_3-C\equiv C-CH_3 + KBr + H_2O$ (Sedzeff's rule)

2-Butyne

ii) $CH_2(Br)-CH_2(Br) + KOH \xrightarrow[100-200°C]{alc} CH(Br)=CH_2 + KBr + H_2O$

1,2-Dibromo ethane — Bromoethene

$CH(Br)=CH_2 + KOH \xrightarrow[100-200°C]{alc} CH\equiv CH + KBr + H_2O$

iii) $CH_2(Cl)-CH_2(Cl) + 2KOH \xrightarrow[100-200°C]{alc} CH\equiv CH + 2KCl + 2H_2O$

1,2-Dichloroethane

(B) From Geminal dihalide

$CH_3-\overset{\beta}{C}H_2-\overset{\alpha}{C}H(Br)-Br + NaNH_2 \xrightarrow[-33°C]{Liq.NH_3} CH_3-CH=CH-Br + NaBr + NH_3$

1,1-Dibromo propane

$CH_3-\overset{\beta}{C}H=\overset{\alpha}{C}H-Br + NaNH_2 \xrightarrow[-33°C]{Liq.NH_3} CH_3-C\equiv CH + NaBr + NH_3$

1-propyne

$CH_3-\underset{\underset{Br}{|}}{C}-Br + 2KOH \xrightarrow[210-300°C]{Alc} HC\equiv CH + 2KBr + 2H_2O$

1,1-Dibromoethane
Geminal dihalide

Terminal alkynes → are those in which ≡ bond is after 1st Carbon (CH) is acidic.

$CH_3^3-C^2\equiv \overset{1}{C}H + NaNH_2 \xrightarrow[-33°C]{Liq\ NH_3} CH_3-C\equiv CNa + NH_3$

$^{-\delta}C-H^{+\delta}$ → become polarized due to increase in s-character

$CH_3-C\equiv CNa + \overset{+\delta}{H}-\overset{-\delta}{OH} \longrightarrow CH_3-C\equiv CH + NaOH$

Home-Work

$CH_3-\underset{\underset{Br}{|}}{\overset{Br}{\overset{|}{C}}}-CH_2-CH_3 + 2NaNH_2 \xrightarrow[-33°C]{Liq\ NH_3} CH_3-\overset{Br}{\overset{|}{C}}=CH-CH_3 + NaBr + NH_3$

(terminal Acidic)

$CH_3-\overset{Br}{\overset{|}{C}}=CH-CH_3 + NaNH_2 \xrightarrow[-33°C]{Liq\ NH_3} CH_3-C\equiv C-CH_3 + NaBr + NH_3$

Reactivity:-

Alkene > alkyne > alkane

$C=C$	$C\equiv C$	$C-C$
1.34 A°	1.20 A°	1.54 A°
exposed π bond	More e⁻ density	
	difficult for $E^{\oplus}$ to attack	

$E^{\oplus}$ attack is difficult

Acidity of termind alkyne:

→ Ethyne or 1-alkyne like propyne are Acidic in nature bcz in these alkynes triple bond Carbon is sp hybridized it contains 50% s-character

s-character ∝ polarity

due to more "s" character as compared to sp^2 & sp^3 hybridized C.

$C\equiv C$	$C=C$	$C-C$
sp (s=50%)	sp^2 (s=33.3%)	sp^3 (s=25%)

Due to this $\overset{+\delta\ -\delta}{H-C\equiv C}$ is more E·N so become polar.

- bond polarity created
- Easy to remove H & become Acidic

∴ Hydrogen attach with these carbon (terminal) become electron deficient behave as Acidic.

Electrophillic substitution rxn of Terminal Alkynes:

1- Reaction with Soda amide ($NaNH_2$)

$\overset{+\delta}{H}$ $\overset{+\delta}{Metal}$ substitute

$R-\overset{-\delta}{C}\equiv\overset{+\delta}{CH} + \overset{+\delta}{Na}\overset{-\delta}{NH_2} \xrightarrow[-33°C]{Liq\ NH_3} R-C\equiv CNa + NH_3$

Alkyne
Suppose: Propyne

Sodium alkanide,
Sodium propanide,

2- Reaction with Na metal

$\overset{+\delta}{CH}\equiv\overset{+\delta}{CH} + 2Na \longrightarrow NaC\equiv CNa + H_2$

ethyne

Disodium ethynide (IUPAC)
Disodium acetylide (C.N)

$CH\equiv C-CH_3 + Na \longrightarrow$

3. Reaction with Ammonical Silver nitrate ($AgNO_3$ NH_4OH)

OR

Identification of test for 1-alkyne

"Ethyne or 1-alkyne react with Ammonical silver nitrate produce white ppt"

$\overset{+\delta}{HC}\equiv\overset{+\delta}{CH} + 2\overset{+\delta}{Ag}NO_3 + 2NH_4OH \longrightarrow \underset{\text{white ppt}}{AgC\equiv CAg} + 2H_2O$

Disilver ethynide

$+2NH_4NO_3$
Ammonium Nitrate

Note: Rxn 1 & 2 product are water soluble so we cannot identify 1-alkyne.

⇒ Identification test is rxn 3
- Insoluble in H_2O
- Colour change white ppt

$CH_3-C\equiv C-H + \underbrace{AgNO_3 + NH_4OH}_{\text{tollen reagent}} \longrightarrow CH_3-C\equiv CAg + H_2O + NH_4NO_3$

$\underbrace{CH_3-C\equiv C-CH_3}_{\text{not terminal alkyne}} + AgNO_3 + NH_4OH \longrightarrow$ No reaction

identification Test for 1-alkyne or $[CuCl_2 + NH_4OH]$

4- Rxn with Ammonical Cuprous Chloride:

ous → low Oxidation state ric → high O.S

Cuprous → Cu^{+1} Cupric → Cu^{+2}

Ferous → Fe^{+2} Ferric → Fe^{+3}

Identification test:

* Ethyne or 1- alkyne like 1-propyne, 1-butyne etc react with Ammonical cuprous chloride produce Red ppt

$HC\equiv CH + Cu_2Cl_2 + 2NH_4OH \longrightarrow \overbrace{CuC\equiv CCu}^{\text{red ppt}}$

Dicopper ethynide

$+ 2H_2O + 2NH_4Cl$

$CH_3-C\equiv C-H + 1/2\ Cu_2Cl_2 + NH_4OH \longrightarrow CH_3-C\equiv CCu$

copper propynide

$+ H_2O + NH_4Cl$

SLO Question

Q. How will you distinguish b/w Test / Reactions

① Ethene & Ethyne ② 1-pentyne & 2-pentyne

Uses of alkynes:

1- Preparation
2- Purification
3- Separation
4- Identification

$AgC \equiv CAg + 2HCl \xrightarrow{\Delta} HC \equiv CH + 2AgCl$
White ppt — Acid — + 2AgCl
↓ Purified alkyne

$CuC \equiv CCu + H_2SO_4 \xrightarrow{\Delta} HC \equiv CH + CuSO_4$
Red brown ppt — Dilute — ethyne
Dicopper alkynide

Addition rxns of alkyne :- E^+ add

1. Hydrogenation: Addition of H_2 in a molecule

$HC \equiv CH + H_2 \xrightarrow[200-300^\circ C]{Ni} CH_2 = CH_2$
Ethyne — ethene

other Catalysts: Pt, Pd (at Room Temp)

$CH_2 = CH_2 + H_2 \xrightarrow[200-300^\circ C]{Ni} CH_3 - CH_3$
ethene — ethane

Direct Method:

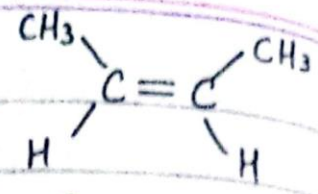
$CH_3 - C \equiv CH + 2H_2 \xrightarrow[200-300^\circ C]{Ni} CH_3 - CH_2 - CH_3$
1-propyne — Propane

(a) Partial Hydrogenation of alkyne

* To make Cis → we use 2-butene (Pd, $BaSO_4$ + Quinoline) — Lindler catalyst

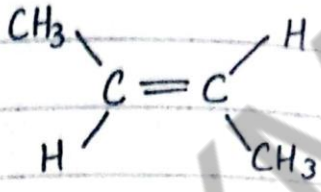
* To make Trans-2-butene (Na + liq NH_3 - 33°C)

$CH_3-C\equiv C-CH_3$ (2-Butyne) $\xrightarrow[\text{Quinoline}]{Pd+BaSO_4}$ (poison to Catalyst)



Cis-2-butene

$CH_3-C\equiv C-CH_3$ (2-Butyne) $\xrightarrow[-33^\circ C]{Na\ liq\ NH_3}$



2. HydroHalogenation: Addition of HX

$HC\equiv CH + \overset{+\delta}{H}-\overset{-\delta}{Cl} \longrightarrow CH_2=\underset{Cl}{CH}$ Vinyl chloride

$CH_2=\underset{Cl}{CH} + \overset{+\delta}{H}-\overset{-\delta}{Cl} \longrightarrow CH_3-\underset{Cl}{\overset{Cl}{CH}}$

Geminal dihalide

1,1-Dichloroethane

$\underset{\text{1-propyne}}{CH_3-C\equiv CH} + H-Br \longrightarrow \underset{\text{1-Bromo-1-propene}}{CH_3-CH=CH-Br}$

$CH_3-CH=CH-Br + HBr \longrightarrow CH_3-CH_2-\underset{Br}{CH}-Br$

1,1-Dibromo Propane

3. Hydration: "Addition of H_2O in molecule"

$HC\equiv CH + \overset{+\delta}{H}-\overset{-\delta}{OH} \xrightarrow[H_2SO_4\ 75^\circ C]{HgSO_4} CH_2=CH-OH$

Venyl alcohol (enol)

$CH_2 = CH(OH)$ ⇌ (rearrangement) $CH_3-C(=O)-H$

(enol) Acetaldehyde / Ethanal

arrow inward → bond formation
arrow outward → bond breaking

$CH_3-C\equiv CH + \overset{+\delta}{H}-\overset{-\delta}{OH} \xrightarrow[H_2SO_4,\ 75°C]{HgSO_4} CH_3-CH(OH)=CH_2$

$CH_3-CH(OH)=CH_2$ ⇌ (rearrangement) $CH_3-CH(=O)-CH_3$

4. Bromination: /Test for unsaturation/
"Addition of Br_2"
→ Inert solvent is used (CCl_4)

$HC\equiv CH + 2Br_2 \xrightarrow[-34°C]{CCl_4} CHBr_2-CHBr_2$

1,1,2,2-Tetrabromo ethane

$CH_3-C\equiv CH + 2Br_2 \xrightarrow[-34°C]{CCl_4} CH_3-CBr_2-CHBr_2$

(Red Brown)

Propyne — 1,1,2,2-Tetrabromo propane

Discappear

$CH_3-CH_3 + Br_2 \xrightarrow{\ //\ }$ No rxn

5. Ozonolysis: "Addition of O_3"

$R-C\equiv C-R + O_3 \longrightarrow$ molozonoid

Molozonoid $\xrightarrow{\text{rearrangement}}$ ozonide $\xrightarrow[H_2O\ 100°C]{Zn}$ $+ H_2O_2$

$\longrightarrow R-\underset{\underset{O}{\|}}{C}-OH + OH-\underset{\underset{O}{\|}}{C}-R$

Carboxylic Acid

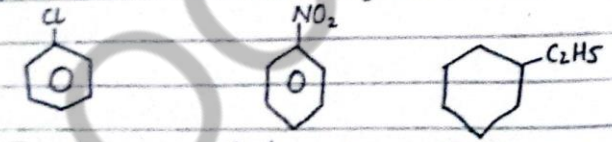
$CH_3-C\equiv C-CH_2-CH_3 + O_3 \xrightarrow[H_2O]{Zn,\ 100°C}$

$CH_3-\underset{\underset{O}{\|}}{C}-OH + OH-\underset{\underset{O}{\|}}{C}-CH_2-CH_3$

Benzene Nomenclature

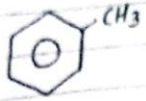
↳ Discovered by Michel Faraday 1825
↳ Isolated by: Hoffman
↳ Molecular weight: 78 amu

① Substituent is named before benzene.

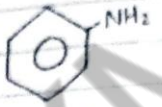


Chlorobenzene Nitrobenzene Ethyl benzene

(2) Special names are included in IUPAC

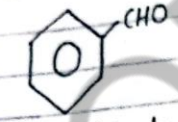


Tolrene
Methyl benzene



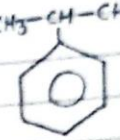
Aniline
Amino benzene

Phenol
Hydroxy benzene



benzaldehyde

Benzoic Acid

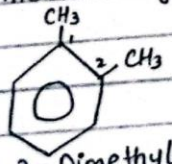


Cumene
Isopropyl benzene

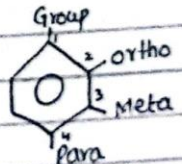
Styrene
Vinyl benzene

Anisol
Methoxy benzene

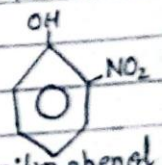
3) When two grps are attached, it will be numbered.



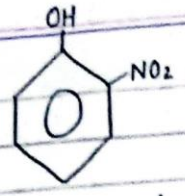
1,2-Dimethyl benzene
(Xylene)



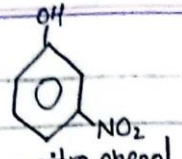
1-2 [ortho]
1-3 [Meta]
1-4 [Para]



O-nitro phenol



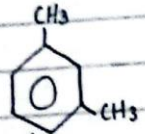
O-Nitro phenol



m-nitro phenol

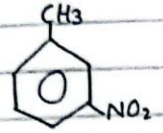
Meta nitrophenol

P-nitro phenol



m-xylene

1,3-Dimethyl benzene

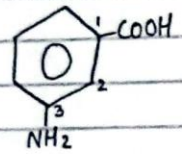


m-nitro tolrene

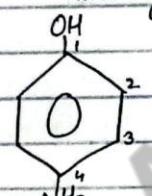
(4) Priority order of different functional groups.

$-COOH$, $C\equiv N$, $\overset{O}{\overset{\|}{C}}-H$, $\overset{O}{\overset{\|}{C}}$, OH , NH_2 , $-OR$, $-R$

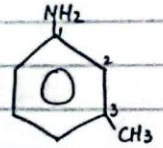
methoxy



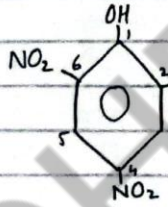
3-Amino Benzoic Acid



4-Amino phenol

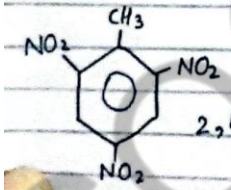


3-methyl Aniline



2,4,6-Trinitro phenol

Picric Acid



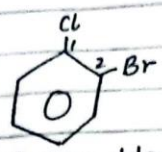
2,4,6-TriNitrotolerene (TNT)

(6) When no group in list then follow alphabetical order

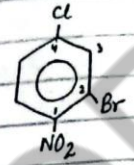
B

C

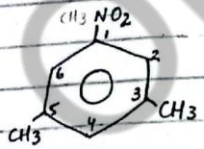
N



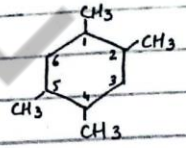
2-Bromochlorobenzene



2-Bromo-4-Chloronitrobenzene



1,3,5-Trimethyl benzene (mesitylene)



1,2,4,5-Tetramethyl benzene (Durene)

Molecular Structure:

Kekule structure

Rhobinson structure

Special Features:

1- Resonance

2- Electrophilic Substitution Rxn

* Benzenes & its derivatives is called Arenes.

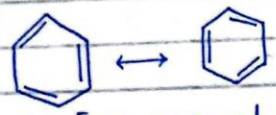
Physical Properties:

→ Benzene is non-polar in nature and not dissolve in polar solvent.

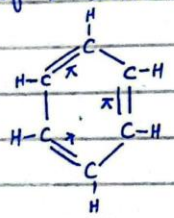
→ low M.P & B.P.

→ In the presence of Polar substituents benzene act as slightly polar compound.

Q. Explain the structure of benzene proposed by Kekule? (3)



The structure proposed by Kekule is very stable. In which benzene contains conjugated double bonds. The structure of benzene is planar hexagonal in nature.



Q. Write down the objections in Kekule structure? (3)

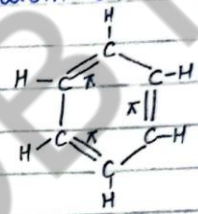
It fails to explain why (less reactive)

1. Why benzene is a stable compound.
2. It shows dual character i.e it shows addition rxn & substitution rxn also.
3. It goes into, substitution reaction readily and addition reaction reluctantly.
3. The bond distances in benzene are all same 1.4 Å°

5. All bonds in benzene are 120°.
6. It has less heat of formation.

Q. Explain Atomic orbital treatment of benzene with the help of diagrams by using hybridization theory. (6)

Each Carbon-atom on benzene ring is 'sp²' hybridized



12 σ
3 π

$C_6 = 1s^{2}, 2s^{2}, 2p_x^{1}, 2p_y^{1}, 2p_z^{0}$

Ground state

$2p_x^{1}\ 2p_y^{1}\ 2p_z^{0}$

$2s^{2}$

Excited state

$2p_x^{1}\ 2p_y^{1}\ 2p_z^{1}$

$2s^{1}$

Hybrid State

$2s^{1}\ 2p_x^{1}\ 2p_y^{1}$

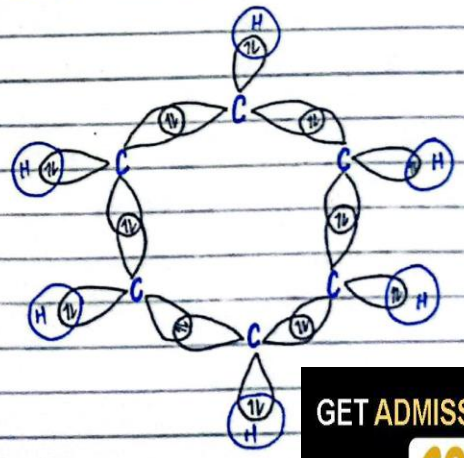
$sp^2\ sp^2\ sp^2$

show 1 loop

UnHybridized

$2p_z^{1}$

$H_1 = 1s^{1}$



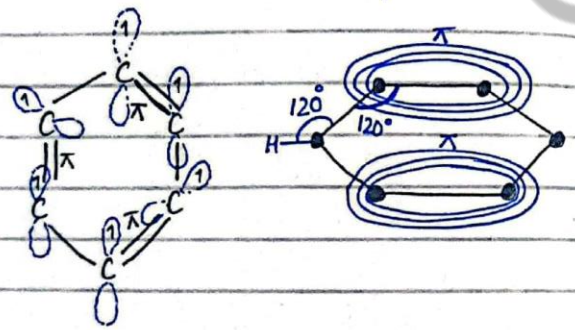
Explanation:

1- Each Carbon atom on benzene ring three sp^2 Hybridized orbitals & one 'sp_z^1' Unhybridized orbital.

2. The three sp^2 Hybridized orbitals form three 'σ' Sigma bonds with adjacent Carbon atoms and One with Hydrogen atom.

3. In this way Sigma framework of benzene is formed having '12 σ' bonds.

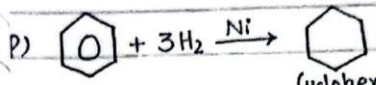
4. The three sp^2 Hybridized orbitals forms three 'π' bonds on Alternate positions.



Q. Compare the stability of benzene with a Hypothetical compound. (6)

Compound with less energy is more stable than with more energy.

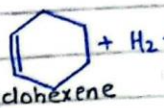
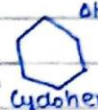
Benzene

P)  + $3H_2$ $\xrightarrow{Ni}$ Cyclohexane

$\Delta H = -208 \frac{KJ}{mol}$

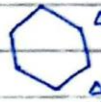
(More stable)

Hypothetical Comp.

(P)  + H_2 $\xrightarrow{Ni}$ 

cyclohexene — Cyclohexane

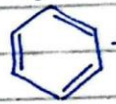
$\Delta H = -120$ KJ/mole

(P)  $+2H_2$ $\xrightarrow{Ni}$ 

1,3-Cyclohexadiene

$\Delta H = -240$

$\Delta H = -231$ (Actual)

(T)  $+3H_2$ $\xrightarrow{Ni}$ 

$\Delta H = -360$ KJ/mol

*No. of bond $\propto$ Unstability

*Unstability $\propto$ Reactivity

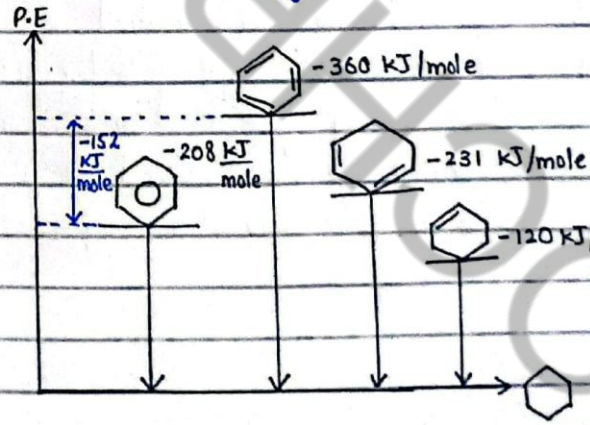
Explanation:

According to heat of hydrogenation data, Benzene produce less heat of Hydrogenation than Hypothetical compound. So, benzene is -152 KJ/mole is more stable than Hypothetical Compound.

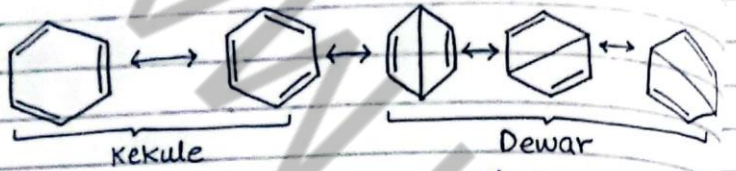
Hypothetical Compound = -360 KJ/mole

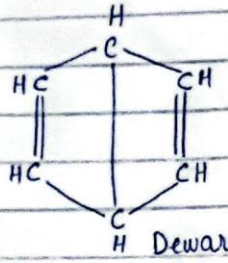
Benzene = -208 KJ/mole

Resonance Energy = -152 KJ/mole



Q. Draw all the Resonance structures of benzene & Explain with the help of diagram.





Dewar

It will show benzene unstable bcz long bond due to more distance & less attraction can be easily broken & become unstable.

Explanation:-

Benzene can be represented by all five resonance structures proposed by Kekule & dewar. But in dewar structures the long bonds b/w $C_1 - C_4$, $C_2 - C_5$ & $C_3 - C_6$ are very weak bond, can be easily attacked by any electrophile which shows that benzene is unstable compound. On the other hand, kekule has conjugated bond system which is v. strong system & represent that benzene is a stable compound. Now we only use kekule structure To represent benzene molecule.

Q. Discuss stability of benzene on the basis of Resonance energy.

Decrease in energy due to resonance is called resonance energy.

Resonance energy = ΔH_{cal} (Theoretical) − ΔH_{obs} (experimental)

OR

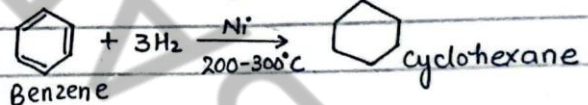
Difference b/w heat of hydration calculated & heat of hydrogenation observed is called resonance.

Resonance energy ∝ Stability

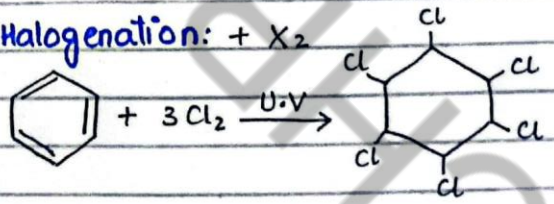
Reaction of Benzene

Ⓐ Addition Rxns: + H_2

→ Catalytic Hydrogenation:



→ Halogenation: + X_2

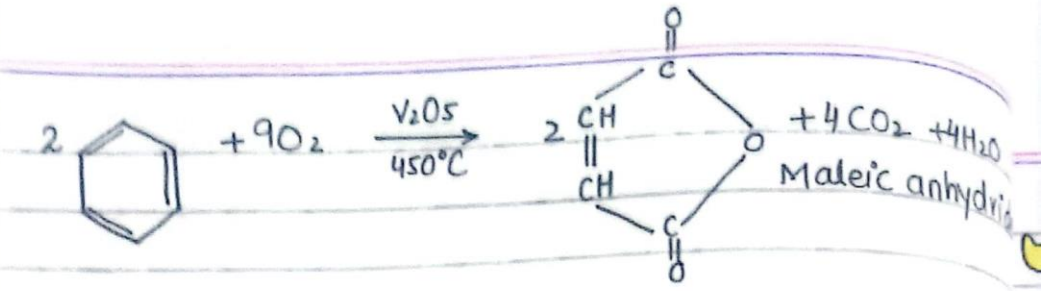


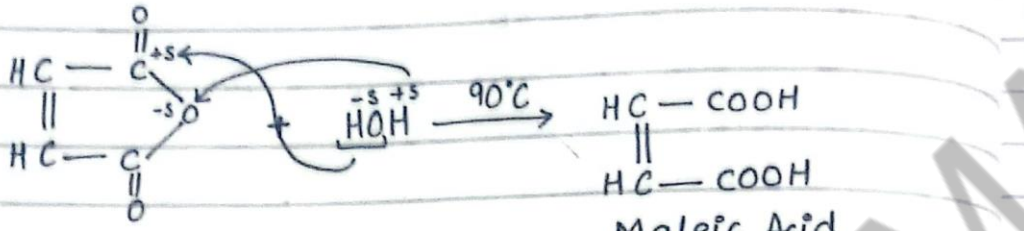
hexachloro cyclohexane

Ⓑ OXIDATION Rxns:

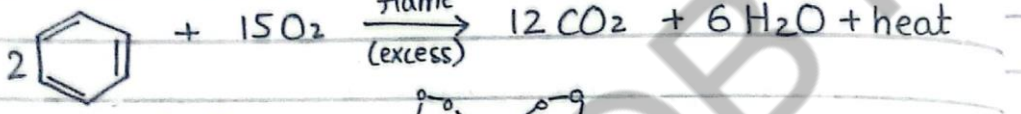
→ Catalytic Oxidation: Benzene cannot be oxidized with $KMnO_4$ & $K_2Cr_2O_7$.

for oxidation of benzene V_2O_5 450°C + O_2

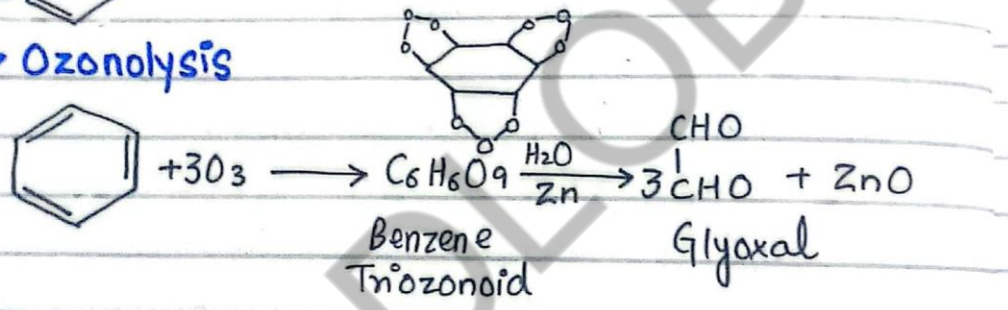




→ Combustion

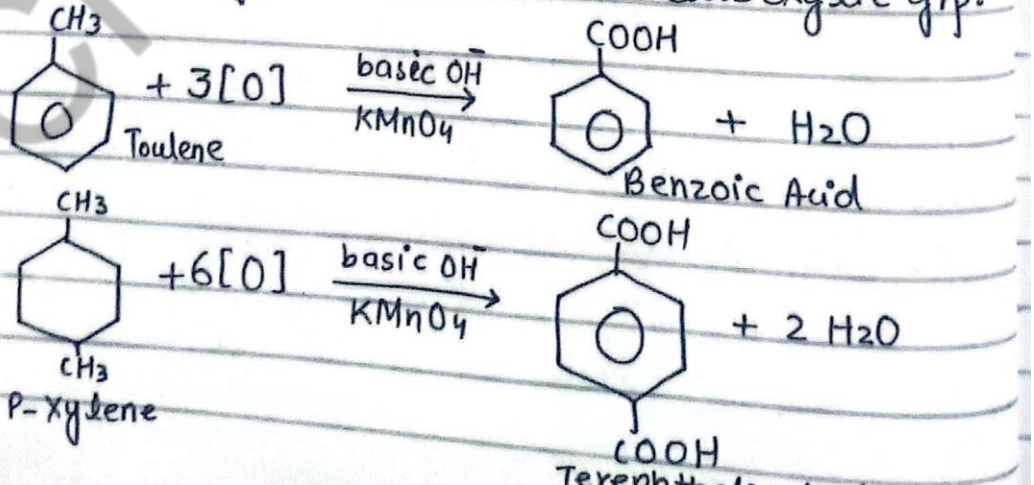


→ Ozonolysis



→ Side Chain Oxidation : Identification Test for alkyl benzene

Benzene does not react with $KMnO_4$ or $K_2Cr_2O_7$ however alkyl group present on benzene ring is oxidized into Carboxylic grp.



This is commercial method for the preparation of maleic anhydride. Benzene is not oxidized by $KMnO_4$ or $K_2Cr_2O_7$.

(ii) Combustion

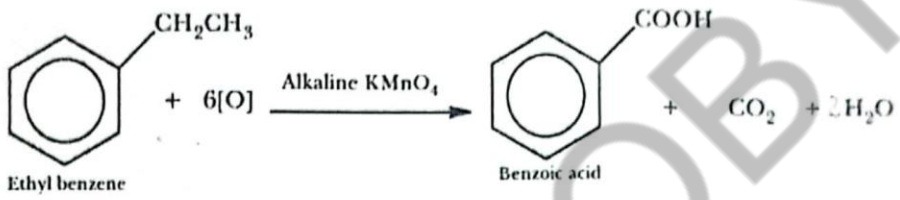
When benzene is burnt in the presence of air or oxygen, CO_2 and H_2O are produced, just as other aliphatic hydrocarbons

(iii) Ozonolysis

Benzene reacts with ozone and gives glyoxal, passing through triozonide as an intermediate

(iv) Side chain Oxidation:

When alkaline or acidic solution of $KMnO_4$ or $K_2Cr_2O_7$ is added to alkyl benzene, alkyl groups present in the benzene ring are oxidized into carboxylic groups.



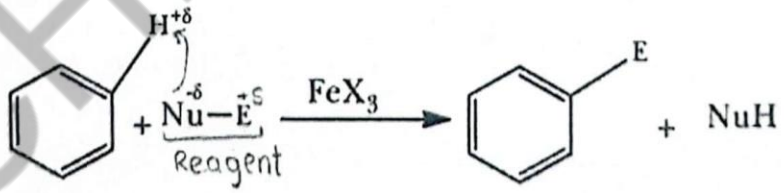
Electrophilic Aromatic Substitution Reactions (-ve is removed & -ve is added)

Introduction

The pi-electrons of benzene are highly stabilized due to resonance. They are not readily available for the electrophilic attack like the electros of alkenes. A weak electrophile cannot attack on benzine ring. Hence more powerful electrophiles are required for a successful attack to penetrate and break the continuous sheath of electron cloud in benzene. Substitution is preferred over addition in order to preserve the stable aromatic character

General reaction

Benzene on reaction with an electrophile in the presence of Lewis acid catalyst gives substituted benzene.



Mechanism / stereochemical evidence

It consists of the following three steps.

1. **Formation of a strong electrophile (X^+)**

$$2Fe + 3X_2 \longrightarrow 2FeX_3$$

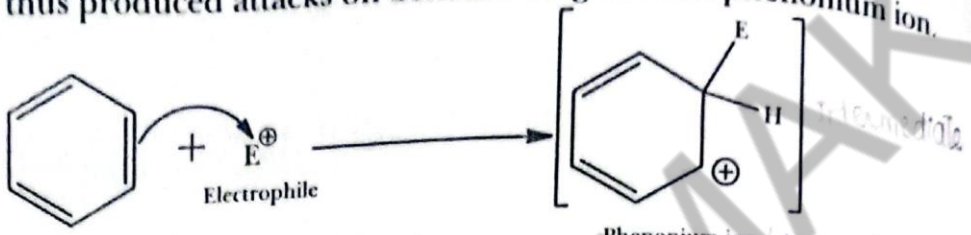
$$\text{①}\quad 2FeX_3 + NuE \longrightarrow [FeX_3Nu]^- + E^+$$

(Catalyst + reagent)

E^+ is a strong electrophile

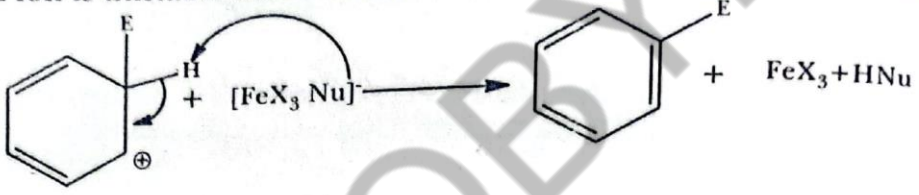
2. Formation of phenonium ion / Attack of electrophile

The electrophile E^+ thus produced attacks on benzene ring to form phenonium ion.



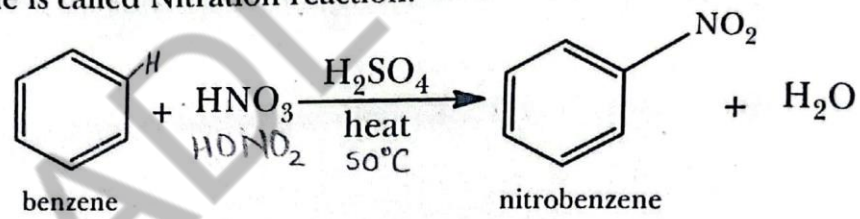
3. Regeneration of catalyst

The phenonium ion is unstable therefore H^+ ion is removed to give substitution product.



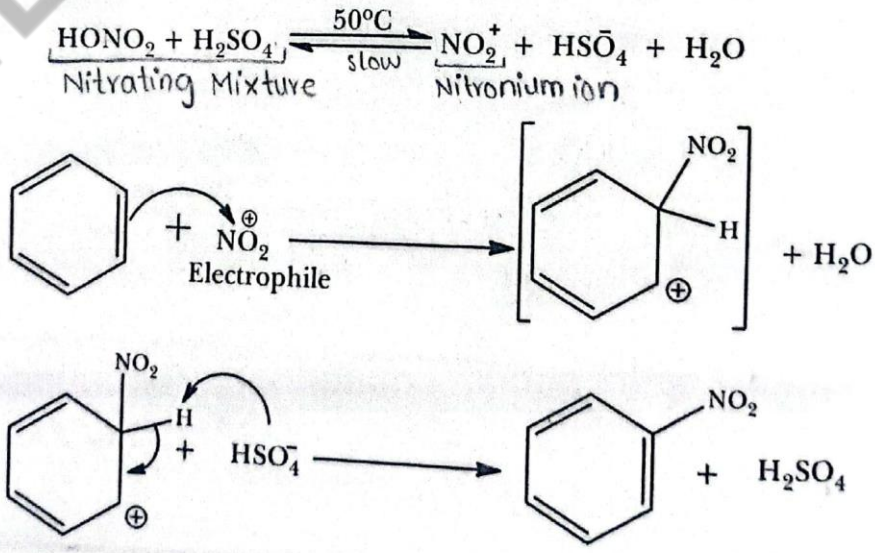
Nitration

The substitution of NO_2 group to a benzene ring in the presence of conc. H_2SO_4 at 50-55 °C form nitrobenzene is called Nitration reaction.



Mechanism

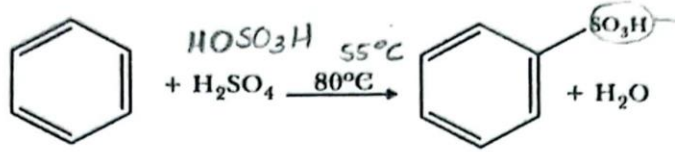
Sulphuric acid reacts with nitric acid to generate nitronium ion.



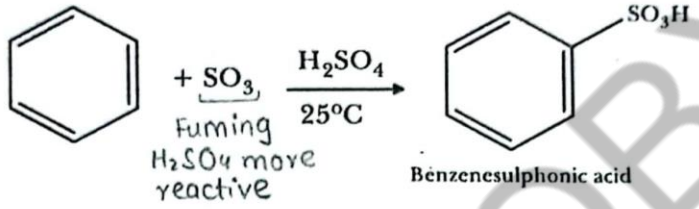
Sulphonation

The substitution of sulphonic acid group to a benzene ring is called Sulphonation. Wh benzene is heated with fuming H_2SO_4 or concentrated H_2SO_4 it yields benzene sulphonic ac

Fuming H_2SO_4 has free sulphur trioxide which is electron deficient (electrophile) and causes substitution.



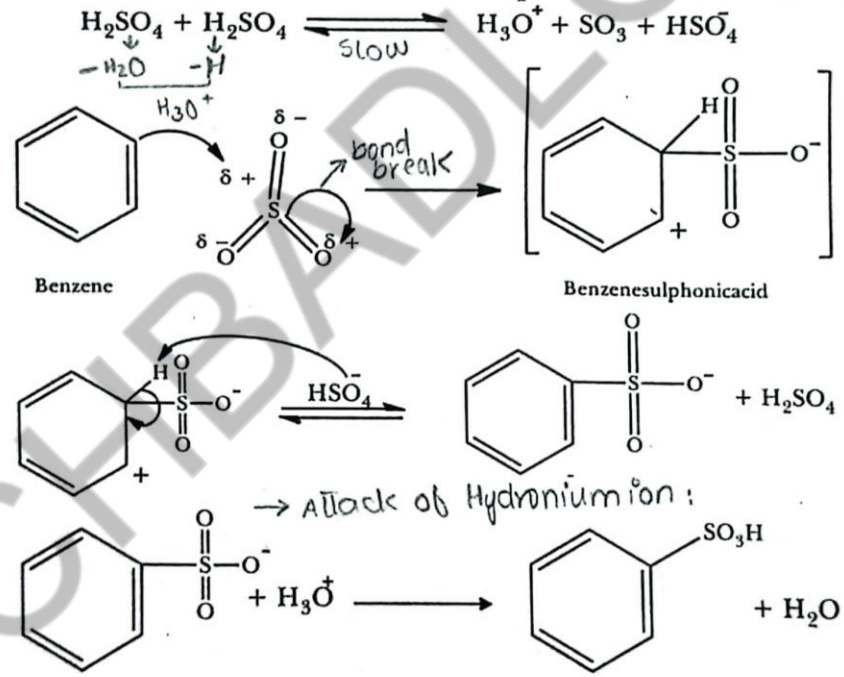
SO_3H → Sulphonic grp



$H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$
fumes oleum

Mechanism

When sulphuric acid alone is used, the actual electrophile in this reaction is SO_3



Halogenation

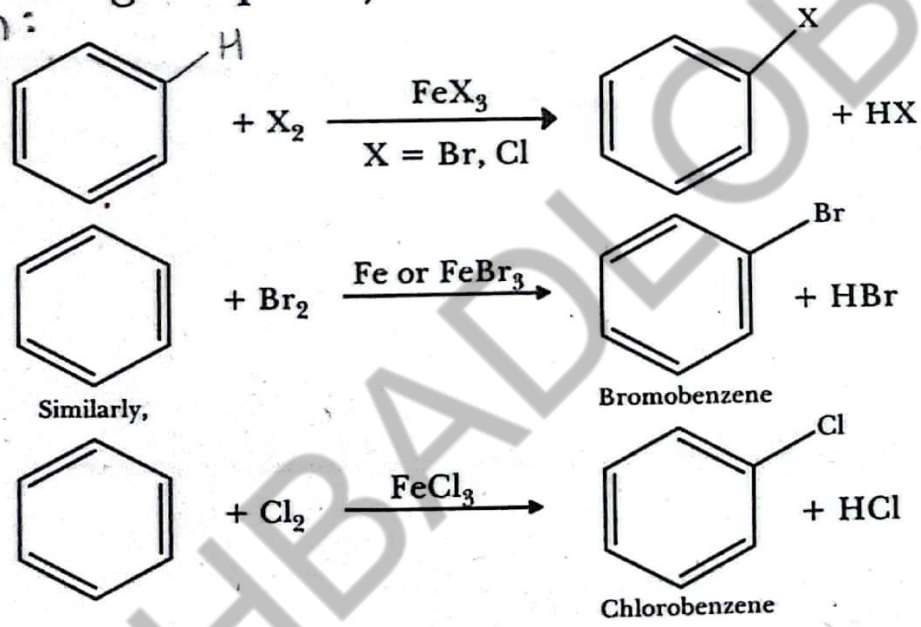
The substitution of halogen to a benzene ring is the

Halogenation

The substitution of halogen to a benzene ring in the presence of a Lewis acid catalyst to form halobenzene is called halogenation reaction.

Halogenation of benzene occurs with halogens (X_2) in the presence of a Lewis acid catalyst FeX_3. Chlorination and bromination are normal reaction but fluorination is too vigorous to control. Iodination gives poor yield.

* Single Step Rxn:



Mechanism

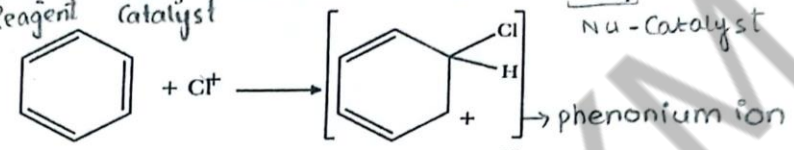
① formation of E^+:

$$X_2 + FeX_3 \longrightarrow X^+ + FeX_4^-$$

$$\underset{\text{Reagent}}{Cl_2} + \underset{\text{Catalyst}}{FeCl_3} \longrightarrow Cl^+ + FeCl_4^-$$

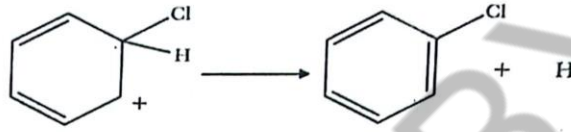
Nu - Catalyst

② Attack of electrophile:



→ phenonium ion

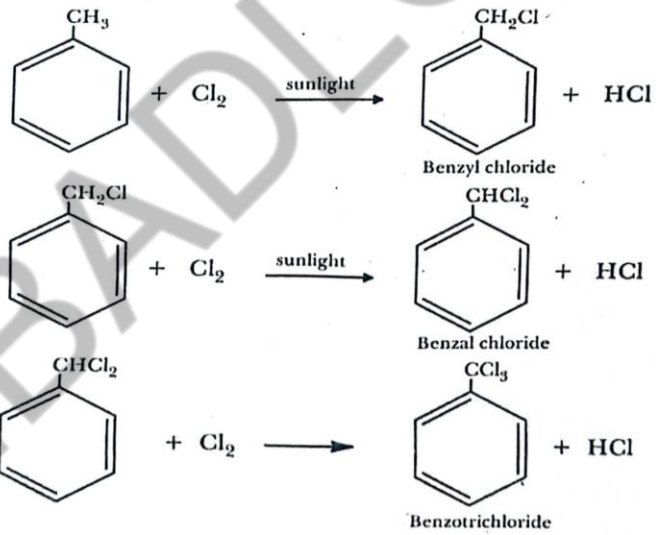
③ loss of Proton



$$H^+ + FeCl_4^- \longrightarrow HCl + FeCl_3$$

Halogenation of alkyl side chain

When alkylated benzene is treated with chlorine or bromine in the presence of sunlight, only the alkyl groups are substituted.



1. Imp

Friedel-Crafts Alkylation Q. Give Friedal craft Alkylation rxn of Benzene?

The substitution of an alkyl group in the benzene ring in the presence of a Lewis acid catalyst $AlCl_3$ to form an alkylated benzene is called Friedel Crafts alkylation reactions.

Q. Convert benzene into tolouene?

Benzotrichloride

M.Imp

Friedel-Crafts Alkylation

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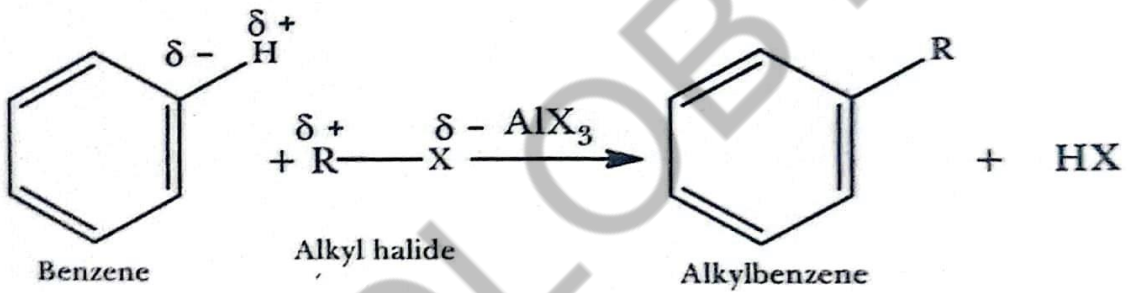
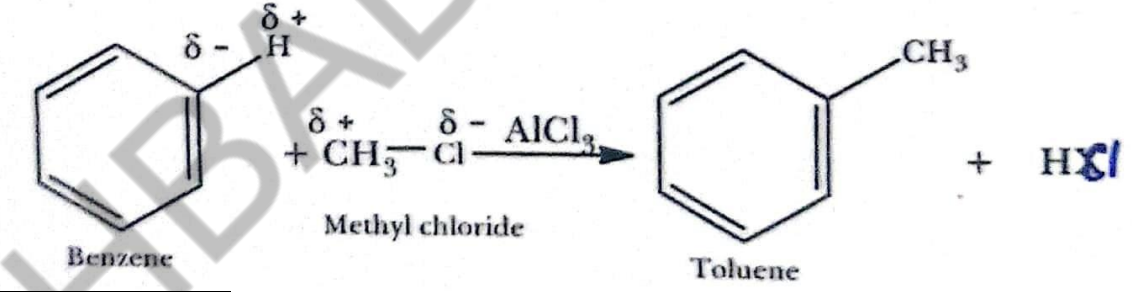
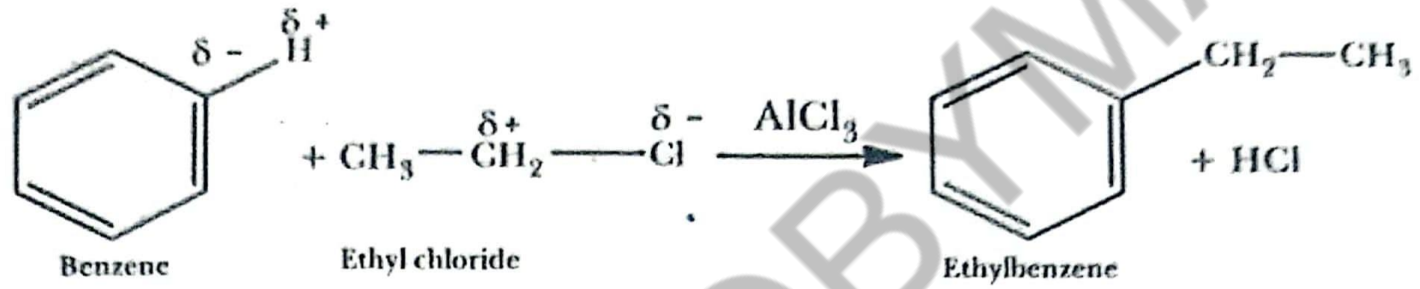
General reaction

Q. Convert benzene into toluene?

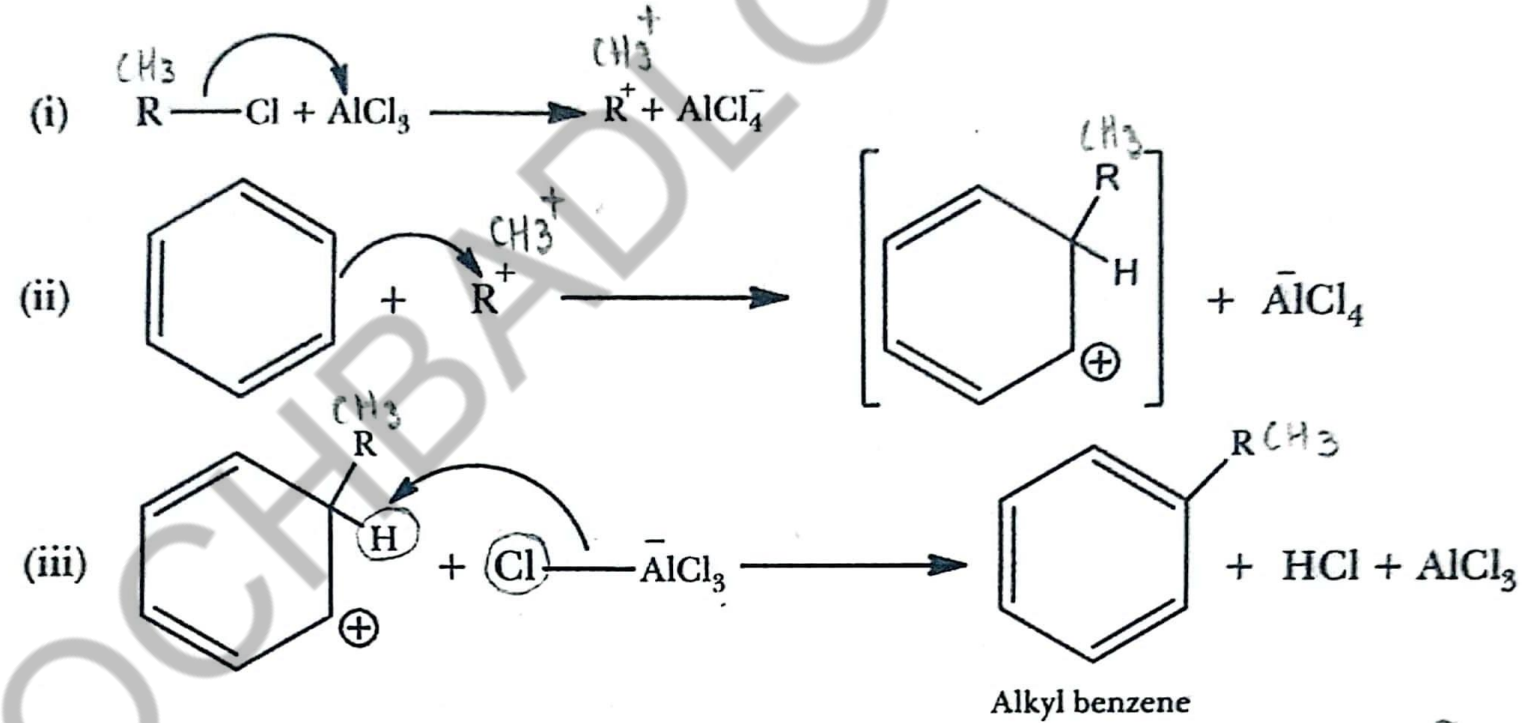


Examples /One-Step Rxn:





Mechanism



* M. Imp

Alkyl benzene

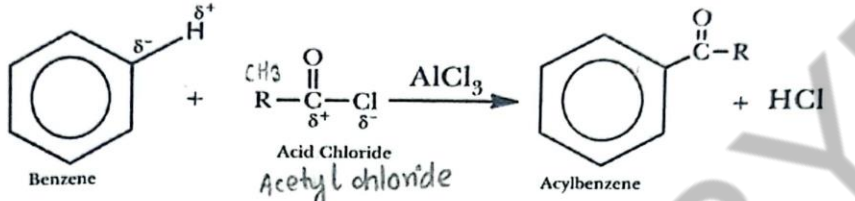
A.u. Imp

Friedel-Crafts Acylation

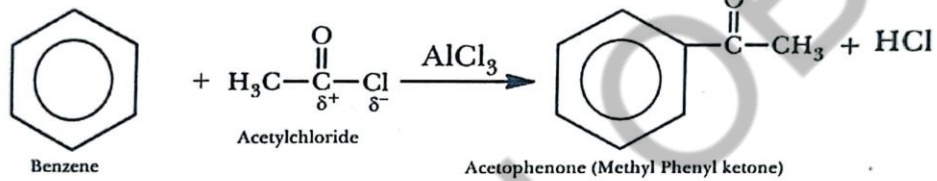
Q. Give Friedal craft acylation Rxn?

The substitution of an acyl group ($RCO^{\ddagger}$) to a benzene ring in the presence of a Lewis acid catalyst such as $AlCl_3$ to form an acetylated benzene is called Friedel Crafts Acylation.

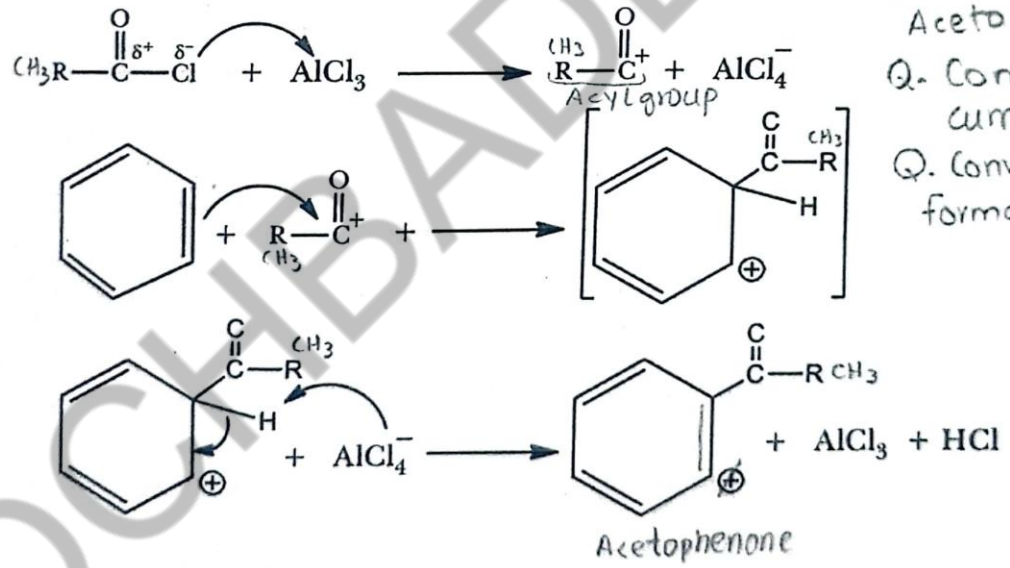
General reaction



Example/One-step Rxn:



Mechanism



Q. Convert benzene into Acetophenone?

Q. Convert benzene cumene by alkylo

Q. Convert benzene int formaldyhide?
↳ take formyl chloride

$\ddot{C}—CH_3 + HCl$

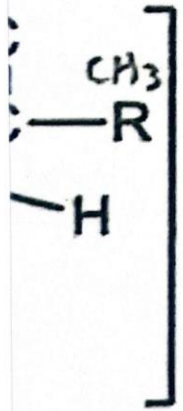
ketone)

Q. Convert benzene into Acetophenone?

Q. Convert benzene into cumene by alkylation?

Q. Convert benzene into formaldyhide?
↳ take formyl chloride

4



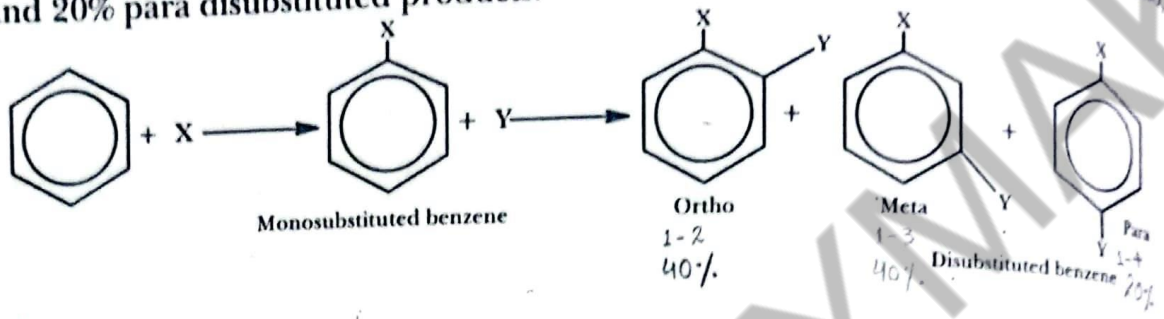
—R CH_3

$+ AlCl_3 + HCl$

The Effect of Substituents (orienting effect)

When an electrophilic substitution reaction takes place on benzene ring, we get only one monosubstituted benzene because all the six positions in the ring are equivalent. However, the position of a second group into the ring depends on the nature of the first group. The second group substituted may enter at ortho, para or meta position.

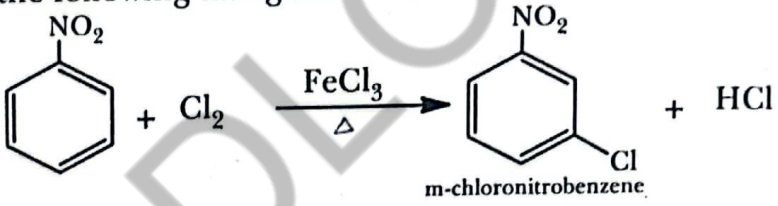
On statistical basis the proportion of disubstituted products would be 40% ortho, 40% meta and 20% para disubstituted products.



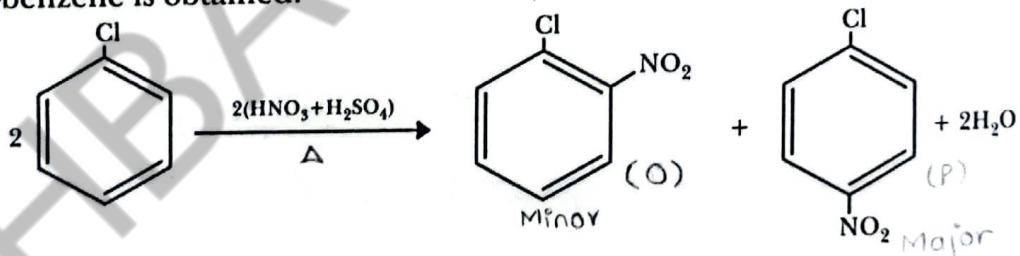
Example

chlorination of nitrobenzene in the presence of Lewis acid catalyst forms 3-nitro chlorobenzene as the main product.

However, the results do not agree with chance substitution ratio, e.g. m-nitro-chlorobenzene the main product of the following halogenation reaction.



However, nitration of chlorobenzene gives a mixture of o-nitrochloro-benzene and p-nitrochloro-benzene is obtained.



Classification of substituent on benzene ring

There are two types of groups:

a. Ortho- and para- directing groups
b. Meta- directing groups

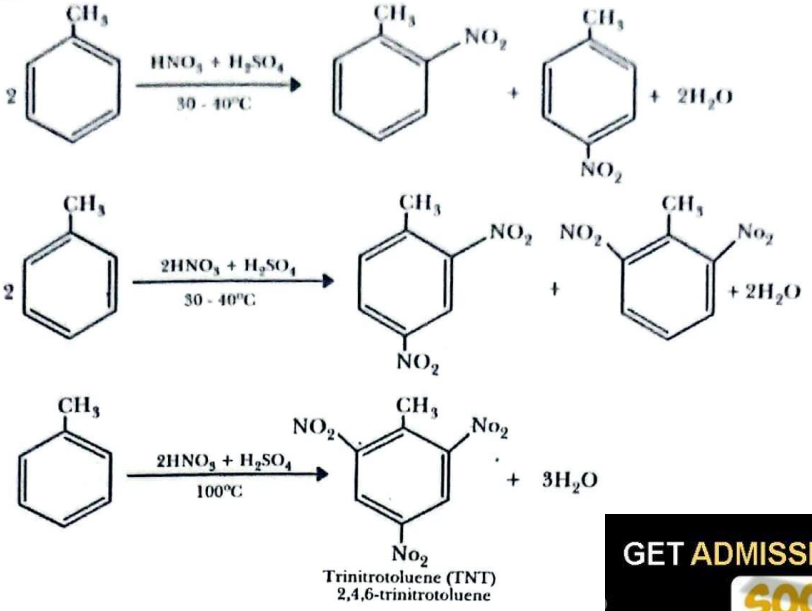
1. Ortho and para directing groups ?

These groups release electrons towards the benzene ring, at ortho and para positions. Because these positions are electron rich, therefore the second group is substituted at ortho and para positions. They also enhance the reactivity of benzene ring.

Example

The electron releasing effect of methyl groups is significant and it makes the ring a good nucleophile. Due to this increased reactivity, more nitro groups can enter the ring

ortho and para positions.



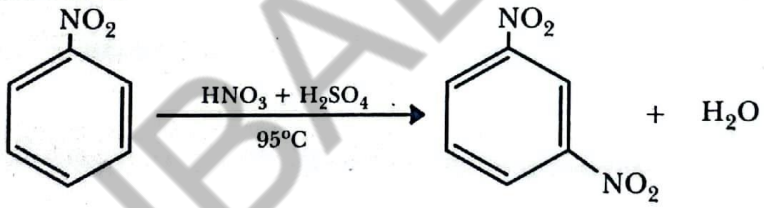
Examples of ortho and para directing groups are

$-N(CH_3)_2$, $-NH_2$, -OH, $-OCH_3$, -Cl, -Br, -I and R-

Although -F, -Cl, -Br and -I are ortho-para directing groups but they deactivate the ring for further substitution.

2. Meta-Directing Groups

These groups withdraw the electrons of the benzene ring from ortho and para positions. Therefore the ortho and para positions are more electrons deficient than the meta position. Thus, the incoming electrophile will prefer to attack on meta position rather than ortho and para positions. These groups are called meta-directing groups. These groups decrease the chemical reactivity of benzene.



The substitution of third nitro groups is not possible because nitro group has deactivated the ring, other examples of meta directing groups are

$-NO_2$,. $-COOH, -CHO, -SO_3H, -CN, -COR$ etc.

Determining the directive, activating and deactivating effects of the substituents

1. All alkyl groups, phenyl group and groups having one or more non bonding electron pairs on the atom adjacent to the ring are ortho-para directing. -R, -OH, -OR, $-NH_2$, -X.
2. substituent having a positive (or partial positive) charge on the atom adjacent to the ring are meta directing groups.

$$-\overset{\overset{O}{\|}}{\overset{+}{N}}-O^-, \quad -\overset{+}{N}H_3, \quad -\overset{+\delta\ -\delta}{C}N \quad \text{etc.}$$

3. All ortho-para directing groups activate the ring except halogens which are partially deactivators.
4. All meta directing groups are deactivators.

- Groups like CN,-CHO, $^{+}NH_3$, $^{+}NR_3$, which decrease the reactivity of Benzene nucleus and direct the incoming group at m- position

Exercise

1: Select the right answer from the choices given with each question.

i. **The molecule of ethane posses which hybridization;**
a. sp^3 b. sp^2 c. sp d. sp^2d

ii. **The sp^2 hybrid orbitals are oriented in space at one angle;**
a. 109.5^0 b. 180^0 c. 100^0 d. 120^0

iii. **The geometry of acetylene is,**
a. angular b. bent c. trigonal d. linear

iv. **Which reaction is used as test for the presence of alkene;**
a. reaction of cold diluted alkaline $KMnO_4$ b. Combustion
c. Polymerization d. Catalytic hydrogenation

v. **The general formula of alkane is;**
a. C_nH_{2n+2} b. C_nH_n c. C_nH_{2n} d. C_nH_{2n-2}

vi. **Sodalime is;**
a. NaOH b. KOH c. Mixture of Na and Ca hydroxide d. CaO and NaOH

vii. **The marsh gas is**
a. Ethane b. Methane c. Propane d. Butane

viii. **Acidic hydrogen is present in**
a. Acetylene b. Ethane c. Benzene d. Ethene

ix. **The electrophile in aromatic sulphonation is;**
a. H_2SO_4 b. HSO^-_4 c. SO_3 d. SO^-_4

x. **Catalyst used for Friedal Craft's reaction is;**
a. HNO_3 b. $MgCl_2$ c. $BeCl_2$ d. $FeCl_3$

xi. **Benzene can not undergo**
a. Elimination b. Substitution c. Oxidation d. Addition

xii. **Shape of benzene molecule is**
a. Pyramidal b. Liner planar c. Trigonal d. Hexagonal
planar

xiii. **The isomers of a substance must have**
(a) same chemical properties (b) same molecular weight
(c) same structural formula (d) same functional groups

xiv. **Ethanol and dimethyl ether are best considered:**
(a) structural isomers (b) stereosierms (c) enantiomers (d) diasteromers

xv. **Alkenes show geometrical isomers due to**
(a) asymmetry (b) rotation around a single bond
(c) resonance (d) restricted rotation around a double bond

xvi. **Geometrical isomerism is shown by**
(a) lactic acid (b) maleic acid (c) 1-butene (d) 1,1-
dichloroethylene

xvii. **A molecule is said to be chiral**
(a) if it contains plane of symmetry (b) it contains center of symmetry
(c) if it cannot be superimposed on its mirror image
(d) if it can be superimposed on its mirror image

xviii. **Which of the statements is false regarding chiral compounds**
(a) rotate the plane of polarized light (b) have cis and tans isomers
(c) exist as enantiomers (d) can be detected with a polarimeter

xix. **An optically active compound**
(a) must contain at least four carbons
(b) when in solution rotate the plane of polarized light
(c) must always contain an asymmetric carbon atom
(d) in solution always give a negative reading in polarimeter

xx. **Plane polarized light is affected by**
(a) identical molecules (b) all polymers
(c) chiral molecules (d) all biomolecules

xxi. **It is possible to distinguish between optical isomers**
(a) by using chemical tests (b) by mass spectrometry
(c) by IR spectroscopy (d) by polarimetry

2: Answer the following questions briefly.

1. What is cis-trans isomerism?
2. Why alkanes are relatively chemically inert?
3. Alkenes usually undergo addition reactions while alkanes do not why?