

E-CONTENT FOR COMPLETE COURSE

e-book:

PHARMACEUTICAL ORGANIC CHEMISTRY-II

(BP301T)

(For B.Pharm 3rd Semester Student)

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COURSE CONTENT:

General methods of preparation and reactions of compounds superscripted with asterisk (*) to be explained To emphasize on definition, types, classification, principles/mechanisms, applications, examples and differences

UNIT I

Benzene and its derivatives

A. Analytical, synthetic and other evidences in the derivation of structure of benzene, Orbital picture, resonance in benzene, aromatic characters, Huckel's rule

B. Reactions of benzene - nitration, sulphonation, halogenation reactivity, Friedelcrafts alkylation- reactivity, limitations, Friedelcrafts acylation.

C. Substituents, effect of substituents on reactivity and orientation of mono substituted benzene compounds towards electrophilic substitution reaction

D. Structure and uses of DDT, Saccharin, BHC and Chloramine

UNIT II

Phenols* - Acidity of phenols, effect of substituents on acidity, qualitative tests, Structure and uses of phenol, cresols, resorcinol, naphthols

Aromatic Amines* - Basicity of amines, effect of substituents on basicity, and synthetic uses of aryl diazonium salts

Aromatic Acids* –Acidity, effect of substituents on acidity and important reactions of benzoic acid.

UNIT

10 Hours

Fats and Oils

a. Fatty acids – reactions.

b. Hydrolysis, Hydrogenation, Saponification and Rancidity of oils, Drying oils.

c. Analytical constants – Acid value, Saponification value, Ester value, Iodine value, Acetyl value, Reichert Meissl (RM) value – significance and principle involved in their determination.

UNIT IV

Polynuclear hydrocarbons:

a. Synthesis, reactions

b. Structure and medicinal uses of Naphthalene, Phenanthrene, Anthracene, Diphenylmethane, Triphenylmethane and their derivatives

UNIT V

Cyclo alkanes*

Stabilities – Baeyer's strain theory, limitation of Baeyer's strain theory, Coulson and Moffitt's modification, Sachse Mohr's theory (Theory of strainless rings), reactions of cyclopropane and cyclobutane only

CHAPTER-1

TOPIC- Analytical, synthetic and other evidences in the derivation of structure of benzene, Orbital picture, resonance in benzene, aromatic characters, Huckel's rule

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Derivation of the Structure of Benzene and Its Aromatic Character

1. Introduction

Benzene (C_6H_6) is a fundamental aromatic compound with a unique **cyclic planar structure**, exceptional **stability**, and distinctive **reactivity patterns**. The structure of benzene was not obvious from its molecular formula alone, and understanding its true nature involved **analytical, synthetic, spectroscopic, and theoretical studies**. Today, benzene is best represented using concepts from **molecular orbital theory, resonance, and Hückel's rule**.

2. Analytical and Synthetic Evidences for the Structure of Benzene

2.1 Molecular Formula and Degree of Unsaturation

The molecular formula of benzene is C_6H_6 , suggesting a high degree of unsaturation (index of hydrogen deficiency = 4). This could correspond to **three double bonds and one ring**, but its reactivity and properties deviate from typical alkenes.

2.2 Lack of Addition Reactions

Unlike alkenes, benzene does **not readily undergo addition reactions**. For example, it resists bromination without a catalyst and prefers **substitution reactions** (e.g., electrophilic aromatic substitution), indicating exceptional stability and **delocalization of π -electrons**.

2.3 Equal Bond Lengths (Spectroscopic Evidence)

X-ray diffraction and spectroscopic studies show that **all carbon-carbon bond lengths in benzene are equal**: approximately 1.39 \AA , intermediate between a typical C–C single bond (1.54 \AA) and a C=C double bond (1.34 \AA).

2.4 Heat of Hydrogenation

The heat of hydrogenation of benzene is significantly **less exothermic** than expected. Cyclohexene gives -119 kJ/mol . Three such double bonds should release $\sim -357 \text{ kJ/mol}$.

Benzene, however, gives only -208 kJ/mol, indicating it is **149 kJ/mol more stable** than expected for a cyclic triene—evidence for **resonance stabilization**.

2.5 Substitution Product Patterns

Benzene undergoes **monosubstitution** reactions (e.g., nitration, sulfonation) producing a **single isomer**, indicating **all hydrogens are equivalent**, supporting a **highly symmetrical structure**.

3. Kekulé's Structure and its Limitations

3.1 Kekulé's Proposal (1865)

Kekulé proposed a **cyclic structure** with **alternating single and double bonds**:

- Two resonance forms exist by **interchanging double bonds**.
- The actual molecule is a **resonance hybrid** of both forms.

3.2 Limitations of Kekulé's Structure

- Predicts **alternating bond lengths**, not supported by experimental data.
- Does not explain **extraordinary thermodynamic stability**.
- Fails to fully account for **uniform reactivity** at all six carbon atoms.

4. Modern Orbital Picture of Benzene

4.1 Hybridization and σ Framework

Each carbon atom in benzene is **sp^2 hybridized**:

- Three sp^2 orbitals form **σ bonds**: two with adjacent carbon atoms and one with a hydrogen.
- The six carbon atoms form a **planar hexagonal ring**.

4.2 Unhybridized p Orbitals and π -System

Each carbon has one unhybridized **p orbital** perpendicular to the ring plane. These **six p orbitals overlap laterally**, forming a **delocalized π -electron cloud** above and below the ring.

- The π -electrons are **not localized** between specific carbon atoms.
- Instead, they are **delocalized over the entire ring**, contributing to benzene's **stability and aromaticity**.

5. Resonance in Benzene

Benzene is best represented as a **resonance hybrid** of two Kekulé structures:



The actual molecule:

- Has **equal bond lengths** throughout.
- Is **more stable** than either resonance contributor.
- Possesses **resonance energy** of ~149 kJ/mol.

The resonance stabilizes the structure and explains:

- Chemical inertness toward addition
- Preference for substitution reactions
- Equal reactivity of all positions on the ring

6. Aromatic Character and Hückel's Rule

6.1 Definition of Aromaticity

A molecule is **aromatic** if it satisfies the following criteria:

- **Cyclic**
- **Planar**
- **Fully conjugated** (every atom in the ring has a p orbital)
- Contains **$(4n + 2)$ π -electrons**, where n is a non-negative integer (Hückel's Rule)

6.2 Hückel's Rule

Derived from quantum mechanical calculations by **Erich Hückel**, the rule states:

A monocyclic, planar, conjugated system is aromatic if it contains $(4n+2)$ π -electrons. A monocyclic, planar, conjugated system is aromatic if it contains $(4n + 2)$ π -electrons. A monocyclic, planar, conjugated system is aromatic if it contains $(4n+2)$ π -electrons.

Where $n = 0, 1, 2, 3 \dots$

6.3 Application to Benzene

- Benzene has **6 π -electrons**
- Plugging into Hückel's Rule: $4n + 2 = 6 \rightarrow n = 1$
- Therefore, benzene is **aromatic**

6.4 Consequences of Aromaticity

- Enhanced thermodynamic stability
- Unique chemical behavior (substitution vs. addition)
- Characteristic **diamagnetic ring currents** (NMR evidence)
- High symmetry and planarity

7. Summary

Property	Benzene's Behavior
Molecular formula	C_6H_6 (high degree of unsaturation)
Reactivity	Undergoes substitution, not addition
Bond lengths	All C–C bonds are equal (1.39 Å)
Thermodynamic stability	High (149 kJ/mol resonance energy)
Resonance	Resonance hybrid of two Kekulé structures
Orbital picture	Delocalized π -system formed by overlapping p orbitals
Aromaticity	Satisfies Hückel's rule (6 π -electrons, $n = 1$)

Hückel's Molecular Orbital (MO) Theory

1. Introduction

Hückel's Molecular Orbital (HMO) Theory, developed by **Erich Hückel** in the 1930s, is a quantum mechanical model used to explain the **electronic structure** and **stability of planar conjugated π -systems**, particularly **aromatic compounds**.

The theory focuses on **π -electrons**, ignoring σ -bonding electrons (which are treated as a stable framework). By solving the **Schrödinger equation** for π -electrons in conjugated systems, Hückel's method helps predict:

- Molecular orbitals
- Electron configurations
- Stability (aromaticity) of the system

2. Basic Assumptions of Hückel Theory

Hückel's MO theory uses the **Linear Combination of Atomic Orbitals (LCAO)** approximation and is built on the following key assumptions:

1. **Only π -electrons are considered** (σ -framework remains unchanged).
2. Each carbon atom contributes **one p_z orbital** to the π -system.
3. These p_z orbitals interact only with **adjacent p_z orbitals**.
4. The interaction parameters are:
 - **α (alpha):** Coulomb integral (energy of an electron in an isolated p orbital)

- β (beta): Resonance integral (stabilization due to overlap between neighboring p orbitals)
- $S = 0$: Overlap between atomic orbitals is neglected (simplification)

3. Hückel's π Molecular Orbital Diagram for Benzene (C_6H_6)

3.1 Structure of Benzene

- Benzene has **6 carbon atoms** arranged in a planar hexagon.
- Each carbon is **sp^2 -hybridized** and has a perpendicular **unhybridized p orbital**.
- These **6 p orbitals combine** to form **6 π molecular orbitals**.

3.2 Energy Levels and Symmetry

Solving the secular determinant for benzene yields **6 π -molecular orbitals** with the following energy levels (in units of β):

MO	Energy ($\alpha + x\beta$)	Degeneracy	Number of Electrons
ψ_1	$\alpha + 2\beta$	1	2
ψ_2, ψ_3	$\alpha + \beta$	2 (degenerate)	4 (2 each)
ψ_4, ψ_5	$\alpha - \beta$	2 (degenerate)	0
ψ_6	$\alpha - 2\beta$	1	0

3.3 π -Electron Configuration of Benzene

- Benzene has **6 π -electrons**.
- These electrons fill the **lowest three bonding MOs** (ψ_1, ψ_2, ψ_3).
- Result: **Completely filled bonding orbitals** and empty antibonding orbitals ($\psi_4-\psi_6$)

This electronic configuration explains benzene's:

- **Extraordinary thermodynamic stability**
- **Equal bond lengths** (due to electron delocalization)
- **Resistance to addition reactions** (as breaking aromaticity is unfavorable)

4. Hückel's $(4n + 2)$ π -Electron Rule

Using the outcomes of his MO theory, Hückel proposed a simple empirical rule:

A monocyclic, planar, fully conjugated system is aromatic if it contains $(4n + 2)$ π -electrons, where n is an integer (0, 1, 2, ...).

4.1 Examples

Compound	π -Electrons	n	Aromatic?
Benzene (C ₆ H ₆)	6	1	Yes
Cyclopentadienyl anion	6	1	Yes
Cyclobutadiene	4	1	No (Anti-aromatic)
Cycloheptatrienyl cation (tropylium ion)	6	1	Yes
Naphthalene (C ₁₀ H ₈)	10	2	Yes

5. Antiaromaticity and Nonaromaticity

5.1 Antiaromatic Compounds

- **Planar, cyclic, fully conjugated**, but contain **4n π -electrons**
- Example: **Cyclobutadiene (4 π -electrons)**
- These compounds are **highly unstable** due to electron pairing in degenerate orbitals

5.2 Non-Aromatic Compounds

- Do not satisfy one or more criteria for aromaticity
- May be **acyclic**, **non-planar**, or **non-conjugated**
- Example: **Cyclohexene**, **cyclopentadiene**

6. Significance of Hückel's MO Theory

Hückel's theory provides valuable insights into:

- **Stability trends** in conjugated hydrocarbons
- **Prediction of aromaticity**
- **Orbital symmetry** in pericyclic reactions (basis for Woodward-Hoffmann rules)
- Foundation for **modern computational chemistry**

Despite being **semi-empirical** and **limited to planar π -systems**, it successfully explains the behavior of a vast number of **aromatic molecules** and **heterocycles** (e.g., pyrrole, furan, thiophene).

7. Summary

Concept	Description
Hückel Theory	MO approach for π -electrons in conjugated, planar cyclic systems
Criteria for Aromaticity	Planar, cyclic, conjugated, (4n + 2) π -electrons
Benzene's π -system	6 p orbitals \rightarrow 6 π -MOs, 3 bonding and 3 antibonding

Concept**Description**

Resulting configuration Filled bonding orbitals → stability and equal bond lengths

Antiaromatic compounds $4n$ π -electrons → destabilized due to electron pairing

VBSPU

CHAPTER-2

TOPIC- Reactions of benzene- nitration, sulphonation, halogenation reactivity, Friedelcrafts alkylation reactivity, limitations, Friedelcrafts acylation.

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Reactions of Benzene

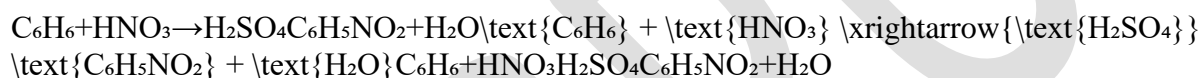
1. Introduction

Benzene, an aromatic hydrocarbon with a stable π -electron system, predominantly undergoes **electrophilic aromatic substitution (EAS)** reactions rather than addition reactions. The delocalized electrons in benzene confer **aromatic stability**, which is preserved during substitution.

The most important EAS reactions of benzene include **nitration**, **sulphonation**, **halogenation**, **Friedel–Crafts alkylation**, and **acylation**.

2. Nitration of Benzene

Reaction:

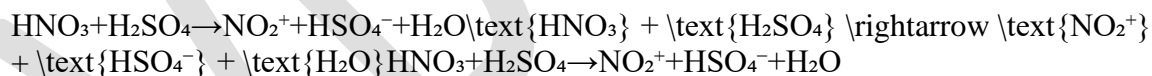


Reagents:

- Concentrated **nitric acid** and **sulfuric acid**

Mechanism:

1. Generation of Electrophile (NO_2^+):



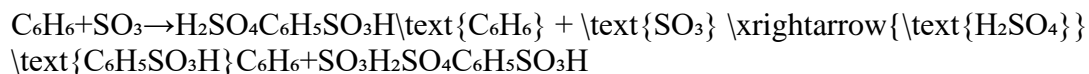
- Attack on benzene ring** to form the sigma complex.
- Loss of proton** to restore aromaticity.

Use:

- Production of **nitrobenzene**, precursor to aniline, dyes, and explosives.

3. Sulphonation of Benzene

Reaction:



Reagents:

- Fuming sulfuric acid ($\text{H}_2\text{SO}_4 + \text{SO}_3$)

Mechanism:

- Formation of the **sulfonium ion** (SO_3H^+) which acts as the electrophile.
- Similar EAS mechanism as nitration.

Reversibility:

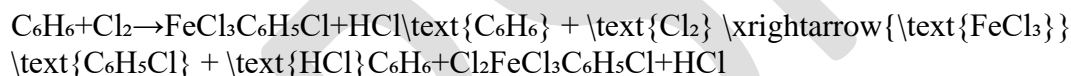
- Sulphonation is **reversible**.
- Desulphonation can occur with **dilute acid and heat**.

Use:

- Important for **directing group manipulation** in synthesis.
- Produces detergents and sulfa drugs.

4. Halogenation of Benzene

Reaction:

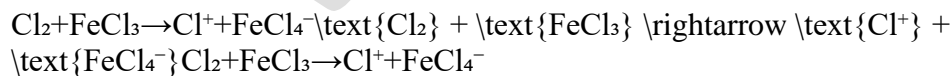


Reagents:

- Halogen (Cl_2 or Br_2)
- **Lewis acid catalyst** (FeCl_3 , FeBr_3 , or AlCl_3)

Mechanism:

1. Activation of halogen:



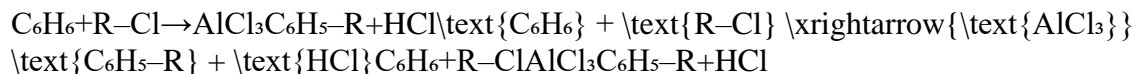
2. **Electrophilic attack** by Cl^+ .
3. **Restoration of aromaticity** by deprotonation.

Use:

- Produces **aryl halides**, used in agrochemicals, pharmaceuticals, and dyes.

5. Friedel–Crafts Alkylation

Reaction:

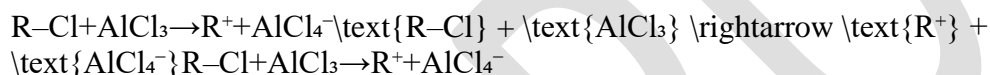


Reagents:

- Alkyl halide (R–Cl)
- Aluminum chloride (AlCl₃)

Mechanism:

1. Generation of carbocation (R⁺):



2. **Electrophilic attack** by carbocation on benzene.
3. **Loss of proton** to restore aromaticity.

Reactivity:

- Carbocations can undergo **rearrangement**, leading to **unexpected products**.
- E.g., 1° carbocations rearrange to 2° or 3° forms.

Limitations:

- Not effective with:
 - Aryl halides or vinyl halides (don't form stable carbocations)
 - Deactivated rings (e.g., nitrobenzene)
- **Polyalkylation** may occur due to increased activation of the ring post-substitution.

6. Friedel–Crafts Acylation

Reaction:



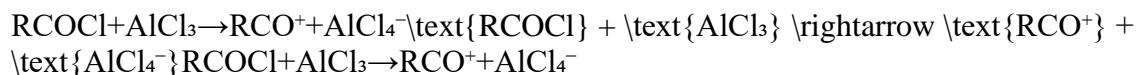
Reagents:

- Acid chloride (RCOCl)

- **Aluminum chloride (AlCl₃)**

Mechanism:

1. Formation of acylium ion:



2. **Electrophilic attack** on benzene.
3. **Deprotonation** and restoration of aromaticity.

Advantages over alkylation:

- No **rearrangement** (acylium ion is resonance-stabilized).
- Product is **less reactive** than benzene, preventing polyacylation.

Use:

- Introduction of **ketone functionality** into aromatic rings.
- Intermediate for pharmaceuticals, perfumes, and dyes.

7. Comparative Reactivity and Summary

Reaction	Electrophile	Catalyst	Rearrangement	Poly-substitution
Nitration	NO ₂ ⁺	H ₂ SO ₄	No	Minimal
Sulphonation	SO ₃ or SO ₃ H ⁺	H ₂ SO ₄	No	Reversible
Halogenation	Cl ⁺ /Br ⁺	FeCl ₃ , AlCl ₃	No	Some
Friedel–Crafts Alkylation	R ⁺	AlCl ₃	Yes	Yes
Friedel–Crafts Acylation	RCO ⁺	AlCl ₃	No	No

8. Conclusion

Benzene and its derivatives primarily undergo **electrophilic aromatic substitution** due to the stability of their aromatic system. The **nature of the electrophile**, **type of catalyst**, and **electronic effects of substituents** greatly influence the **rate** and **orientation** of substitution. While reactions like **nitration**, **sulphonation**, and **halogenation** are widely used, **Friedel–Crafts reactions** provide powerful tools for building complex aromatic compounds—though their **limitations** must be carefully managed.

CHAPTER-3

TOPIC- Substituents, effect of substituents on reactivity and orientation of mono substituted benzene compounds towards electrophilic substitution reaction

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Substituents: Their Effects on Reactivity and Orientation in Electrophilic Aromatic Substitution (EAS)

1. Introduction

Electrophilic aromatic substitution (EAS) reactions involve the replacement of a hydrogen atom on the benzene ring with an electrophile, while retaining the aromaticity. When benzene is **monosubstituted**, the nature of the substituent already attached to the ring plays a crucial role in determining:

- The **rate** (reactivity) of substitution.
- The **position** (orientation) where the new group enters: **ortho (o-)**, **meta (m-)**, or **para (p-)**.

These effects are governed by **electronic properties** of the substituent, which may activate or deactivate the ring, and influence the **electron density** at specific positions.

2. Classification of Substituents Based on Reactivity

2.1 Activating Groups

These increase the electron density in the benzene ring, making it **more reactive** toward electrophiles. They usually:

- Donate electrons via **resonance** or **inductive effects**.
- Direct new substituents to **ortho and para positions**.

Examples: $-\text{OH}$, $-\text{NH}_2$, $-\text{OCH}_3$, $-\text{CH}_3$, $-\text{C}_2\text{H}_5$

2.2 Deactivating Groups

These withdraw electron density from the benzene ring, making it **less reactive** toward electrophiles. They usually:

- Pull electrons via **-I (inductive)** or **-R (resonance)** effects.
- Direct incoming groups to the **meta position** (with exceptions).

Examples: $-\text{NO}_2$, $-\text{COOH}$, $-\text{SO}_3\text{H}$, $-\text{CN}$, $-\text{CHO}$, $-\text{COOH}$, $-\text{COOR}$

3. Orientation Effects (Ortho/Meta/Para Directing)

3.1 Ortho and Para Directing Groups

These groups increase the electron density at the **ortho and para positions** through **lone pair resonance donation** or **hyperconjugation**.

Mechanism Example: Anisole (methoxybenzene)

- The $-\text{OCH}_3$ group donates electrons via resonance:
 - The oxygen's lone pair interacts with the π system of the ring.
 - This increases electron density at ortho and para positions.
- Thus, electrophiles preferentially attack those positions.

Examples:

Group	Type of Effect	Directing
$-\text{OH}$, $-\text{NH}_2$	+R (strong resonance)	Ortho/Para
$-\text{OCH}_3$, $-\text{CH}_3$	+R or +H (hyperconjugation)	Ortho/Para

3.2 Meta Directing Groups

These groups **withdraw electrons** from the ring via $-\text{I}$ and/or $-\text{R}$ effects, reducing electron density particularly at ortho and para positions, making the **meta position relatively more reactive**.

Mechanism Example: Nitrobenzene

- The $-\text{NO}_2$ group is strongly **electron-withdrawing**.
- Through resonance, it **removes electron density** from ortho and para positions.
- Meta position is least deactivated $\rightarrow \text{E}^+$ attacks there.

Examples:

Group	Type of Effect	Directing
$-\text{NO}_2$, $-\text{CN}$	$-\text{R}$ and $-\text{I}$	Meta
$-\text{SO}_3\text{H}$, $-\text{COOH}$	$-\text{R}$ and $-\text{I}$	Meta
$-\text{CHO}$, $-\text{COOR}$	$-\text{R}$ (moderate)	Meta

4. Halogens – Special Case

Halogens ($-\text{Cl}$, $-\text{Br}$, $-\text{I}$) are **deactivating** due to strong $-\text{I}$ effects, but are **ortho/para directing** due to their ability to **donate electrons by resonance**.

This dual behavior makes them **electron-withdrawing overall**, yet they still **guide substitution to ortho and para positions**.

5. Resonance and Inductive Effects Summary

Effect	Description	Examples
+R (resonance donation)	Delocalization of lone pair into ring → activates ring	–OH, –NH ₂ , –OR
+H (hyperconjugation)	Donation of electrons from alkyl groups	–CH ₃ , –C ₂ H ₅
–I (inductive withdrawal)	Electron withdrawal via σ -bond	–NO ₂ , –CN, –Cl, –COOH
–R (resonance withdrawal)	Withdrawal via π -system → deactivates ring	–NO ₂ , –COOH, –SO ₃ H

6. Summary Table: Substituent Effects on Benzene

Substituent	Reactivity	Directing Effect	Type of Group
–OH	Activating	Ortho/Para	Strong +R
–NH ₂	Activating	Ortho/Para	Strong +R
–OCH ₃	Activating	Ortho/Para	Moderate +R
–CH ₃	Activating	Ortho/Para	Hyperconjugation (+H)
–Cl, –Br	Deactivating	Ortho/Para	–I, weak +R
–NO ₂	Deactivating	Meta	Strong –R and –I
–CHO	Deactivating	Meta	–R and –I
–COOH	Deactivating	Meta	–R and –I
–SO ₃ H	Deactivating	Meta	–R and –I

7. Practical Implications in Synthesis

- The **choice of starting material** and knowledge of **substituent effects** allows for **regioselective synthesis**.
- For example:
 - Toluene** (–CH₃) reacts with nitric acid to give **ortho and para nitrotoluene**.
 - Nitrobenzene** reacts with sulfuric acid to give **meta-nitrobenzenesulfonic acid**.
- Strategic use of sulfonation** as a **temporary blocking group** helps control orientation in multi-step syntheses.

8. Conclusion

Substituents on a benzene ring significantly influence the **reactivity and orientation** of further electrophilic substitution. Activating groups accelerate the reaction and direct new substituents to **ortho and para** positions, while deactivating groups slow down the reaction and often direct to the **meta** position. Understanding the **electronic nature** of substituents (via resonance and inductive effects) is critical in designing efficient synthetic pathways in aromatic chemistry.

Substituent Effects in Electrophilic Aromatic Substitution (EAS)

1. Substituent Classification by Reactivity

Activating Groups:

- Increase electron density on the benzene ring.
- Make the ring more reactive toward electrophiles.
- Direct new groups to **ortho** and **para** positions.

Examples: $-\text{OH}$, $-\text{NH}_2$, $-\text{OCH}_3$, $-\text{CH}_3$

Deactivating Groups:

- Withdraw electron density from the ring.
- Decrease reactivity toward electrophiles.
- Usually direct substitution to the **meta** position.

Examples: $-\text{NO}_2$, $-\text{COOH}$, $-\text{SO}_3\text{H}$, $-\text{CHO}$

◆ 2. Direction of Substitution

Ortho/Para Directors (Activating or Resonance Donors):

$-\text{OH}$, $-\text{NH}_2$, $-\text{OCH}_3$, $-\text{CH}_3$, $-\text{Cl}^*$, $-\text{Br}^*$

(*Halogens are deactivating by induction but direct ortho/para by resonance.)

Meta Directors (Strong Electron Withdrawers):

$-\text{NO}_2$, $-\text{COOH}$, $-\text{CHO}$, $-\text{SO}_3\text{H}$, $-\text{CN}$, $-\text{COOR}$

◆ 3. Resonance Effects

Activating Example: $-\text{OH}$

- Donates lone pair via resonance
- Increases electron density at **ortho/para** positions

Deactivating Example: $-\text{NO}_2$

- Withdraws electron density via $-\text{R}$ and $-\text{I}$ effects
- Depletes ortho/para electron density \rightarrow **meta** substitution is favored

◆ 4. Summary Table

Substituent	Reactivity	Directing	Mechanism
$-\text{OH}$, $-\text{NH}_2$	Activating	Ortho/Para	+R (resonance donation)

Substituent	Reactivity	Directing	Mechanism
-CH ₃	Activating	Ortho/Para	+H (hyperconjugation)
-OCH ₃	Activating	Ortho/Para	+R
-Cl, -Br	Deactivating	Ortho/Para	-I (inductive), weak +R
-NO ₂	Deactivating	Meta	-R and -I (strong withdrawal)
-COOH, -CHO	Deactivating	Meta	-R and -I

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CHAPTER-4

TOPIC- Structure and Uses of DDT, Saccharin, BHC, and Chloramine

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Structure and Uses of DDT, Saccharin, BHC, and Chloramine

1. DDT (Dichlorodiphenyltrichloroethane)

IUPAC Name: 1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane

Molecular Formula: $C_{14}H_9Cl_5$

Uses:

- Insecticide used historically for controlling malaria and typhus.
- Effective against mosquitoes, lice, and agricultural pests.
- Banned or restricted due to **bioaccumulation** and **ecotoxicity**.

2. Saccharin

IUPAC Name: 1,2-Benzisothiazol-3(2H)-one 1,1-dioxide

Molecular Formula: $C_7H_5NO_3S$

Uses:

- Artificial sweetener (**300–500 times sweeter than sugar**).
- Used in diabetic products, soft drinks, toothpaste, and food.
- **Non-nutritive** and approved for safe use globally.

3. BHC (Benzene Hexachloride)

IUPAC Name: 1,2,3,4,5,6-Hexachlorocyclohexane

Molecular Formula: $C_6H_6Cl_6$

Uses:

- Used as a pesticide in agriculture.
- **γ -isomer (Lindane)** used to treat lice and scabies.
- Restricted use due to toxicity and environmental concerns.

4. Chloramine

Common Form: Monochloramine (NH_2Cl)

Uses:

- Water disinfectant in municipal water treatment.
- Medical antiseptic (e.g., Chloramine-T).
- Preferred over chlorine in some systems due to **stability** and **reduced by-products**.

Summary Table

Compound	IUPAC Name	Main Use	Key Note
DDT	1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane	Insecticide (banned in many regions)	Persistent pollutant
Saccharin	1,2-Benzisothiazol-3(2H)-one 1,1-dioxide	Artificial sweetener	Non-caloric, FDA-approved
BHC	1,2,3,4,5,6-Hexachlorocyclohexane	Insecticide, lice treatment (γ -isomer)	Multiple isomers; γ is active
Chloramine	Monochloramine (NH_2Cl)	Water and surface disinfectant	More stable than chlorine

CHAPTER-5

TOPIC- Phenols*

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Phenols

1. Introduction

Phenols are a class of **aromatic organic compounds** that consist of a **hydroxyl group (-OH)** directly bonded to an **aromatic benzene ring**. They differ from alcohols, where the -OH group is attached to a saturated carbon atom. The unique structure of phenols gives them **distinctive physical, chemical, and pharmacological properties**, making them important in both **industrial** and **pharmaceutical** fields.

2. General Formula



Where Ar = aromatic ring (usually benzene).

Example:

Phenol ($\text{C}_6\text{H}_5\text{OH}$) is the simplest member of the phenol family.

3. Classification of Phenols

Based on the number of -OH groups:

Type	Examples
Monohydric	Phenol, cresol
Dihydric	Catechol, resorcinol, hydroquinone
Trihydric	Pyrogallol, phloroglucinol

Based on substitution on the ring:

- **Simple phenols:** phenol, cresol
- **Substituted phenols:** thymol, eugenol
- **Polyphenols:** have more than one -OH group (e.g., catechol)

4. Physical Properties

- **State:** Colorless to pale pink crystalline solids (may darken due to oxidation)
- **Solubility:** Slightly soluble in water; readily soluble in alcohol, ether
- **Odor:** Characteristic medicinal, tar-like odor
- **Melting point:** 40–43°C

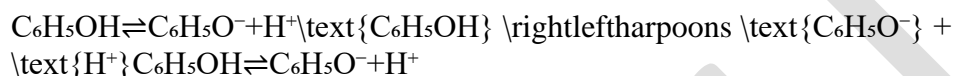
- **Boiling point:** 181°C (phenol)

5. Acidic Nature of Phenols

Phenols are **more acidic than alcohols**, but **less acidic than carboxylic acids**.

Reason:

- The phenoxide ion formed after deprotonation is stabilized by **resonance** over the aromatic ring.

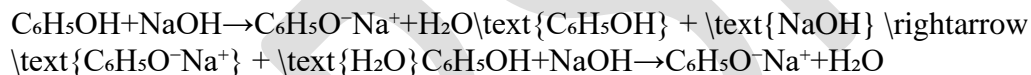


Resonance in phenoxide ion distributes the negative charge, stabilizing it, thus making phenols weak acids ($\text{pK}_a \approx 10$).

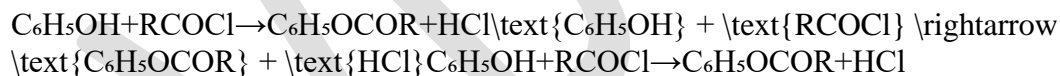
6. Chemical Reactions of Phenols

6.1. Reactions due to –OH group:

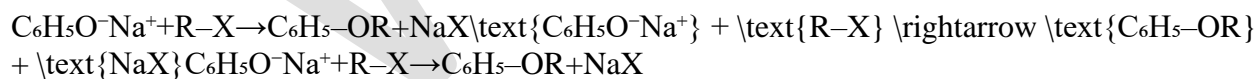
a. Formation of salts (acid-base reaction):



b. Esterification:



c. Ether formation (Williamson synthesis):



6.2. Electrophilic Aromatic Substitution Reactions

Phenol activates the benzene ring towards electrophilic substitution, favoring **ortho and para** positions due to electron-donating –OH group.

a. Nitration:

$\text{C}_6\text{H}_5\text{OH} + \text{HNO}_3 \rightarrow \text{dil. H}_2\text{SO}_4 \text{ -/p-nitrophenol}$
 $\text{C}_6\text{H}_5\text{OH} + \text{HNO}_3 \xrightarrow{\text{dil. H}_2\text{SO}_4} \text{o-/p-nitrophenol}$

b. Bromination:

$\text{C}_6\text{H}_5\text{OH} + \text{Br}_2 \rightarrow 2,4,6\text{-tribromophenol}$
 $\text{C}_6\text{H}_5\text{OH} + \text{Br}_2 \rightarrow 2,4,6\text{-tribromophenol}$

c. Sulphonation, Friedel–Crafts reactions also occur more readily than in benzene.

7. Tests for Phenols

1. Ferric Chloride Test:

- Purple, blue, or green coloration indicates presence of phenolic –OH group.

2. Liebermann's Test:

- Reaction with NaNO_2 and H_2SO_4 gives red, blue, or green coloration.

8. Industrial and Pharmaceutical Uses

Industrial Uses:

- Production of **plastics** (e.g., Bakelite)
- Synthesis of **dyes, explosives** (e.g., picric acid)
- Antioxidants, UV stabilizers**

Pharmaceutical Uses:

- Antiseptics and disinfectants** (phenol, cresol, thymol)
- Ingredient in **mouthwashes, lozenges, ointments**
- Used in synthesis of **aspirin, paracetamol, and salicylic acid**

9. Toxicity and Handling

- Phenol is **toxic, corrosive**, and can be absorbed through the skin.
- Causes **burns, CNS depression, and renal toxicity** in large doses.
- Handle with gloves, goggles, and under fume hood if in lab setting.

10. Examples of Medicinal Phenols

Name	Structure Feature	Use
Thymol	Phenol with isopropyl group	Antiseptic, mouthwash
Eugenol	Methoxy-phenol from clove oil	Dental analgesic
Salicylic acid	o-Hydroxybenzoic acid	Acne treatment, keratolytic
Paracetamol	Acetylated p-aminophenol	Antipyretic, analgesic

Summary

- Phenols are **aromatic compounds** with hydroxyl groups directly attached to the benzene ring.
- They show **acidic character**, undergo **electrophilic substitution** at ortho/para positions, and have **diverse applications**.
- Widely used in **medicine**, **disinfection**, and **industry**, but require careful handling due to **toxicity**.

CHAPTER-6

TOPIC- Aromatic Amines

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Aromatic Amines

1. Introduction

Aromatic amines are organic compounds that contain an **amino group** ($-\text{NH}_2$, $-\text{NHR}$, or $-\text{NR}_2$) directly attached to an **aromatic ring** such as benzene or naphthalene. These compounds are important intermediates in **dyes, drugs, agrochemicals, and polymers**, and exhibit distinct **chemical behavior** due to the influence of the aromatic system on the lone pair of nitrogen.

2. General Structure

$\text{Ar}-\text{NH}_2$, $\text{Ar}-\text{NHR}$, or $\text{Ar}-\text{NR}_2$

Where **Ar** = Aromatic ring (e.g., benzene), and **R** = Hydrogen or alkyl group.

Example:

Aniline ($\text{C}_6\text{H}_5\text{NH}_2$) is the simplest aromatic amine.

3. Classification of Aromatic Amines

Based on substitution on the nitrogen:

Type	Example
Primary ($-\text{NH}_2$)	Aniline
Secondary ($-\text{NHR}$)	N-Methylaniline
Tertiary ($-\text{NR}_2$)	N,N-Dimethylaniline

Based on the number of amino groups:

Name	Structure
Aniline	$\text{C}_6\text{H}_5-\text{NH}_2$
o-Phenylenediamine	$\text{C}_6\text{H}_4(\text{NH}_2)_2$ (1,2-)
m-Phenylenediamine	$\text{C}_6\text{H}_4(\text{NH}_2)_2$ (1,3-)
p-Phenylenediamine	$\text{C}_6\text{H}_4(\text{NH}_2)_2$ (1,4-)

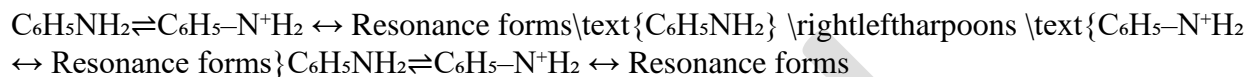
4. Physical Properties

- State:** Generally colorless to pale yellow liquids or low-melting solids

- **Odor:** Characteristic fishy or ammonia-like odor
- **Solubility:** Slightly soluble in water; soluble in organic solvents
- **Boiling Point:** Aniline boils at $\sim 184^{\circ}\text{C}$

5. Basicity of Aromatic Amines

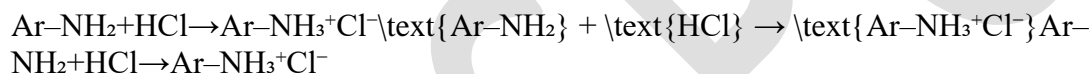
Aromatic amines are **less basic** than aliphatic amines due to **resonance delocalization** of the nitrogen lone pair into the aromatic ring:



This delocalization reduces the availability of the lone pair to accept protons, thus lowering basicity.

6. Chemical Reactions of Aromatic Amines

6.1. Reaction with Acids (Salt Formation)



Forms soluble salts, useful in separation techniques.

6.2. Acylation

Reaction with acid chlorides or anhydrides gives amides.



6.3. Alkylation

Aromatic amines react with alkyl halides to form secondary and tertiary amines.

6.4. Electrophilic Aromatic Substitution

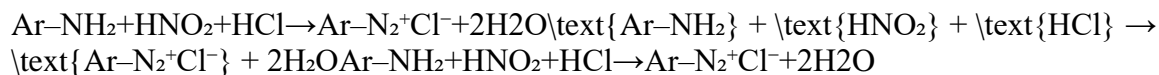
Due to the +R effect of the $-\text{NH}_2$ group, aromatic amines are highly reactive towards electrophilic substitution at **ortho** and **para** positions.

Examples:

- **Nitration** (requires protection due to oxidation risk)
- **Sulphonation**
- **Halogenation:** Often leads to **poly-substitution** unless controlled

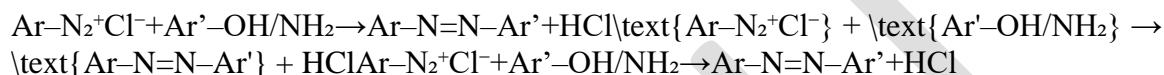
6.5. Diazotization (Important Reaction)

Primary aromatic amines react with nitrous acid ($\text{NaNO}_2 + \text{HCl}$) at $0\text{--}5^\circ\text{C}$ to form **diazonium salts**:



6.6. Coupling Reactions

Diazonium salts can react with phenols or aromatic amines to form **azo dyes**:



7. Tests for Aromatic Amines

a) Carbylamine Test:

- Aromatic primary amines give **foul-smelling isocyanides** with chloroform and KOH.

b) Diazotization and Coupling:

- Red/orange azo dye formation confirms the presence of a primary aromatic amine.

8. Uses of Aromatic Amines

Compound	Uses
Aniline	Dye intermediate, rubber accelerator, paracetamol base
p-Phenylenediamine	Hair dyes, polymers (e.g., Kevlar)
N,N-Dimethylaniline	Methyl orange synthesis
Benzidine	Azo dye precursor (limited due to carcinogenicity)

9. Toxicity and Safety

- Many aromatic amines are **toxic and carcinogenic**.
- Example: **Aniline** can cause **methemoglobinemia**.
- Benzidine** and **β -naphthylamine** are strong **bladder carcinogens**.
- Use with **gloves, fume hood**, and proper **disposal protocols**.

Summary

- Aromatic amines are compounds with -NH_2 or substituted amino groups directly attached to an aromatic ring.
- They are **less basic** than aliphatic amines due to resonance.
- Undergo **acylation, alkylation, electrophilic substitution, diazotization, and coupling**.
- Widely used in **dyes, drugs, and polymers**, but many are **toxic or carcinogenic**.

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CHAPTER-7

TOPIC- Aromatic Acids*

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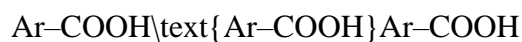
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Aromatic Acids

1. Introduction

Aromatic acids are organic compounds that contain a **carboxylic acid group** (-COOH) directly or indirectly attached to an **aromatic ring** (such as benzene, naphthalene, etc.). These compounds exhibit the **combined properties of aromatic rings and carboxylic acids** and are important in the synthesis of **drugs, dyes, perfumes, and food preservatives**.

2. General Structure



Where Ar = aromatic group (e.g., phenyl ring)

Examples:

- **Benzoic acid** ($\text{C}_6\text{H}_5\text{-COOH}$) – simplest aromatic acid
- **Salicylic acid (2-hydroxybenzoic acid)** – used in acne creams and aspirin synthesis

3. Classification of Aromatic Acids

Based on the position of the -COOH group:

1. **Directly attached** to the aromatic ring:
 - Benzoic acid
 - Toluic acids (o-, m-, p-)
2. **Substituted aromatic acids:**
 - Salicylic acid (-OH group on the ring)
 - Anthranilic acid (-NH_2 group on the ring)
3. **Polycarboxylic acids:**
 - Phthalic acid (1,2-benzenedicarboxylic acid)
 - Terephthalic acid (1,4-benzenedicarboxylic acid)

4. Physical Properties

- **Appearance:** Crystalline solids
- **Solubility:** Sparingly soluble in water; more soluble in hot water, alcohol
- **Melting point:** Benzoic acid $\sim 122^\circ\text{C}$
- **Odor:** Benzoic acid has a faint pleasant smell

5. Acidic Nature

- The **carboxyl group** ($-\text{COOH}$) is the source of acidity.
- **Aromatic acids** are **weak acids** and ionize in water:

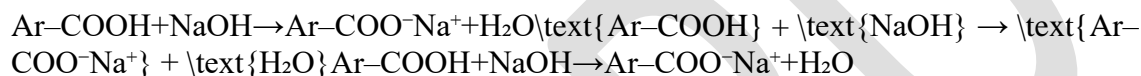


- Acidity is influenced by **substituents** on the ring:
 - **Electron-withdrawing groups** ($-\text{NO}_2$, $-\text{Cl}$) \rightarrow Increase acidity
 - **Electron-donating groups** ($-\text{OH}$, $-\text{CH}_3$) \rightarrow Decrease acidity

6. Chemical Reactions

6.1 Reactions of the $-\text{COOH}$ Group

a. Salt formation:



b. Esterification:



c. Decarboxylation:

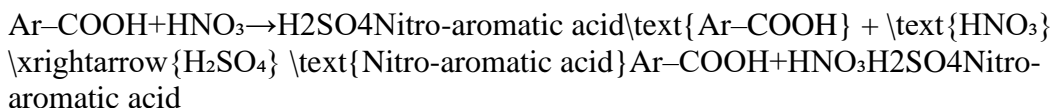


(E.g., heating benzoic acid with soda lime)

6.2 Reactions of the Aromatic Ring

a. Electrophilic substitution (less reactive than benzene due to $-\text{COOH}$ being deactivating):

- **Nitration:**



- **Halogenation:**

$$\text{Ar-COOH} + \text{Br}_2 \xrightarrow{\text{FeBr}_3} \text{Bromo-aromatic acid} + \text{HBr}$$

$$\text{Ar-COOH} + \text{Br}_2 \xrightarrow{\text{FeBr}_3} \text{Bromo-aromatic acid} + \text{HBr}$$

- Substitution occurs mainly at **meta** position ($-\text{COOH}$ is a meta-directing group)

7. Important Aromatic Acids and Their Uses

Aromatic Acid	Structure Feature	Uses
Benzoic acid	$\text{C}_6\text{H}_5-\text{COOH}$	Preservative (E210), antiseptic, plasticizer
Salicylic acid	o-Hydroxybenzoic acid	Used in acne creams, precursor to aspirin
Anthranilic acid	o-Aminobenzoic acid	Intermediate for dyes and perfumes
Phthalic acid	1,2-benzenedicarboxylic acid	Synthesis of plasticizers (e.g., phthalates)
Terephthalic acid	1,4-benzenedicarboxylic acid	Manufacture of polyesters (e.g., PET bottles)
Cinnamic acid	Phenylprop-2-enoic acid	Flavoring agent, fragrance intermediate

8. Tests for Aromatic Acids

1. Sodium bicarbonate test:

- Effervescence due to CO_2 confirms the presence of $-\text{COOH}$ group.

2. Ester test:

- Aromatic acids form esters with alcohols and acid catalyst \rightarrow **fruity smell**.

9. Industrial and Pharmaceutical Importance

- Used as **intermediates** in the manufacture of **dyes, perfumes, polymers**, and **pharmaceuticals**.
- **Benzoic acid** is widely used as a **food preservative**.
- **Salicylic acid** is key to the synthesis of **aspirin** and other **non-steroidal anti-inflammatory drugs (NSAIDs)**.
- **Terephthalic acid** is used in making **polyethylene terephthalate (PET)** for bottles and fibers.

Summary

- Aromatic acids have a -COOH group attached to an aromatic ring.
- They are **weakly acidic**, and show **meta-directing** effects in substitution.
- React chemically like carboxylic acids and participate in **esterification, decarboxylation, and salt formation**.
- Widely used in **food, pharmaceuticals, polymers, and dyes**.

CHAPTER-8

TOPIC- Fatty acids– reactions.

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Fatty Acids – Reactions

1. Introduction

Fatty acids are long-chain **aliphatic carboxylic acids**, typically containing **12 to 24 carbon atoms**, and are major components of **lipids** in living organisms. They may be **saturated** (no double bonds) or **unsaturated** (one or more double bonds).

Fatty acids play a vital role in **energy storage**, **membrane structure**, and **metabolic pathways**. Their carboxyl group ($-\text{COOH}$) and hydrocarbon chain allow them to undergo a variety of **chemical and biochemical reactions**.

2. General Structure



- **Saturated fatty acid:** e.g., palmitic acid ($\text{C}_{16}\text{H}_{32}\text{O}_2$)
- **Unsaturated fatty acid:** e.g., oleic acid ($\text{C}_{18}\text{H}_{34}\text{O}_2$) with a $\text{C}=\text{C}$ bond

3. Classification

- **Saturated fatty acids:** No double bonds (e.g., stearic acid)
- **Monounsaturated fatty acids (MUFA):** One double bond (e.g., oleic acid)
- **Polyunsaturated fatty acids (PUFA):** Two or more double bonds (e.g., linoleic acid)

4. Chemical Reactions of Fatty Acids

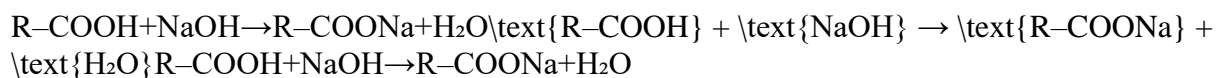
Fatty acids undergo various **chemical reactions** primarily due to the presence of:

1. **Carboxylic acid group ($-\text{COOH}$)**
2. **Unsaturated bonds ($\text{C}=\text{C}$)** in the hydrocarbon chain (if present)

4.1. Reactions of the Carboxylic Group

a) Formation of Salts (Neutralization)

Fatty acids react with bases to form **soaps** (alkali metal salts):



- This is the basis of **saponification**.

b) Esterification

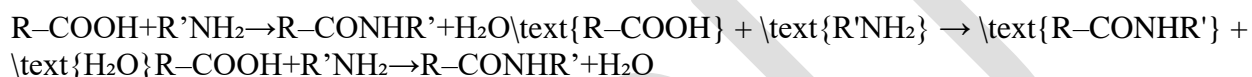
Fatty acids react with alcohols (especially glycerol) in the presence of acid catalysts to form **esters** (fats and oils):



- Reaction with **glycerol** forms **triglycerides** (triacylglycerols).

c) Amide Formation

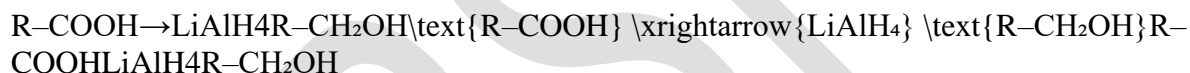
With amines, fatty acids form **amides**:



- Fatty acid amides are found in pharmaceuticals and surfactants.

d) Reduction

Fatty acids can be **reduced to alcohols** using strong reducing agents like **LiAlH₄**:



e) Decarboxylation

Upon heating, especially with soda lime, fatty acids undergo **decarboxylation** to form hydrocarbons:

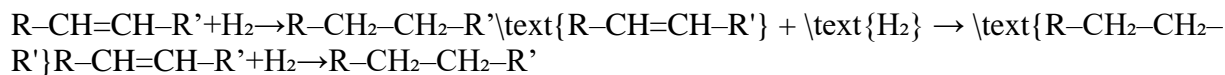


4.2. Reactions of Unsaturated Fatty Acids

These reactions involve the **double bonds (C=C)** present in unsaturated fatty acids.

a) Hydrogenation

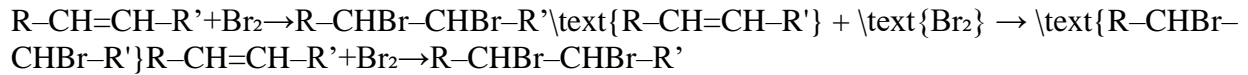
Addition of **H₂** in the presence of **Ni or Pt catalyst** converts unsaturated fatty acids into saturated ones:



- Used in **manufacturing margarine** and solid fats from vegetable oils.

b) Halogenation

Halogens (Br₂ or Cl₂) add across the double bond:



- Used to test for unsaturation (bromine test).

c) Oxidation

- Unsaturated fatty acids undergo **auto-oxidation** in the presence of air and light → leads to **rancidity**.
- Controlled oxidation produces **aldehydes and ketones**.



d) Polymerization (in drying oils)

Unsaturated fatty acids in linseed oil can polymerize on exposure to air → used in **paints and varnishes**.

5. Biochemical Reactions (in vivo)

a) β-Oxidation:

- Catabolism of fatty acids to generate **acetyl-CoA**, which enters the **Krebs cycle** for ATP production.

b) Esterification with Glycerol:

- Formation of **triglycerides** in adipose tissues for **energy storage**.

c) Prostaglandin Synthesis:

- Certain fatty acids like **arachidonic acid** are precursors to **eicosanoids** (prostaglandins, thromboxanes, leukotrienes).

6. Applications

Field	Application
Pharmaceuticals	Drug carriers, emulsifiers, skin formulations
Food	Cooking oils, preservatives, margarine
Industry	Soaps, detergents, cosmetics, lubricants
Medicine	Omega-3 fatty acids → cardiovascular health

Summary

- Fatty acids are **carboxylic acids with long aliphatic chains** (saturated or unsaturated).
- Undergo reactions at **–COOH group** (salt formation, esterification, reduction, decarboxylation).
- Unsaturated fatty acids undergo **addition, oxidation, and polymerization**.
- Play critical roles in **energy metabolism, lipid synthesis, and inflammation regulation**.

CHAPTER-9

TOPIC- Hydrolysis, Hydrogenation,
Saponification and Rancidity of oils,
Drying oils.

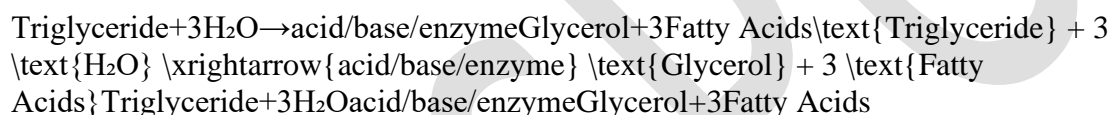
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Hydrolysis, Hydrogenation, Saponification, Rancidity of Oils, and Drying Oils

1. Hydrolysis of Oils

Hydrolysis refers to the chemical breakdown of a compound due to reaction with water. In the context of **fats and oils** (which are **triglycerides**), hydrolysis cleaves the ester bonds, producing **glycerol** and **free fatty acids**.

Reaction:



Types of Hydrolysis:

- **Acidic Hydrolysis:** Carried out in presence of dilute HCl or H₂SO₄
- **Alkaline Hydrolysis:** Basis of saponification (produces soaps)
- **Enzymatic Hydrolysis:** Catalyzed by **lipase enzymes** in biological systems

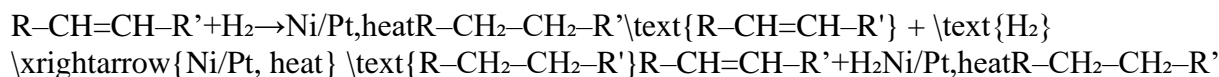
Applications:

- Industrial production of **fatty acids and glycerol**
- Biological lipid digestion in the **intestines**

2. Hydrogenation of Oils

Hydrogenation is the process of **adding hydrogen atoms** across **double bonds** in **unsaturated fatty acids**, converting them to **saturated fatty acids**. This process increases the **melting point** and turns oils into semi-solid fats.

Reaction:



Catalysts: Nickel (Ni), Platinum (Pt), or Palladium (Pd)

Partial Hydrogenation:

- May lead to formation of **trans fats**, which are **unhealthy** and associated with **cardiovascular disease**.

Uses:

- Conversion of **vegetable oils to margarine**
- Improving shelf life and texture of processed foods

3. Saponification

Saponification is the **alkaline hydrolysis of fats and oils**, leading to the formation of **glycerol** and **soap** (alkali salts of fatty acids).

Reaction:

$$\text{Fat/Oil} + \text{NaOH/KOH} \rightarrow \text{Glycerol} + \text{Soap (R-COONa)}$$
$$\text{Fat/Oil} + \text{NaOH/KOH} \rightarrow \text{Glycerol} + \text{Soap (R-COONa)}$$

Soap: Sodium or potassium salt of long-chain fatty acids

Applications:

- Soap and detergent industry
- Analytical chemistry: **saponification number** measures the average molecular weight of fatty acids in fats

4. Rancidity of Oils

Rancidity is the chemical spoilage of fats and oils due to **oxidation or hydrolysis**, leading to unpleasant odor, taste, and color.

Types of Rancidity:

a) Hydrolytic Rancidity:

- Caused by the action of **lipase enzymes** or moisture

- Releases **free fatty acids**, especially **short-chain volatile acids** (e.g., butyric acid)

b) Oxidative Rancidity:

- Occurs in **unsaturated fats**
- Involves **auto-oxidation** at the double bonds, forming **peroxides, aldehydes, and ketones**

Prevention:

- Use of **antioxidants**: BHA, BHT, vitamin E
- **Proper storage**: Cool, dark, airtight conditions

Health Effects:

- Oxidized fats may generate **free radicals**, contributing to **inflammation** and **chronic diseases**

5. Drying Oils

Drying oils are **unsaturated oils** that undergo **oxidative polymerization** when exposed to air, forming a **solid film**. This property makes them useful in **paints, varnishes, and inks**.

Examples:

- **Linseed oil**
- **Tung oil**
- **Poppy seed oil**

Mechanism:

- Presence of **polyunsaturated fatty acids** (linoleic and linolenic acids)
- Absorb oxygen from the air
- Undergo **free-radical polymerization**, forming a **cross-linked network**

Applications:

- Paint and coating industry
- Printing inks
- Wood finishes

Summary Table

Process	Definition	Products	Use/Application
Hydrolysis	Splitting of triglycerides using water	Fatty acids + Glycerol	Digestion, industrial fatty acid production
Hydrogenation	Addition of H ₂ to unsaturated bonds	Saturated fats	Margarine, shelf-stable fats
Saponification	Alkaline hydrolysis of triglycerides	Soap + Glycerol	Soap manufacturing
Rancidity	Spoilage due to oxidation or hydrolysis	Free fatty acids, aldehydes	Degrades food quality
Drying Oils	Oxidative polymerization forming solid films	Crosslinked polymers	Paints, varnishes, inks

CHAPTER-9

TOPIC- Analytical constants– Acid value, Saponification value, Ester value, Iodine value, Acetyl value, Reichert Meissl (RM) value– significance and principle involved in their determination.

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Analytical Constants of Fats and Oils

Analytical constants are standardized values used to **characterize, identify, and assess the quality and purity** of fats and oils. These constants help in detecting **adulteration, degradation**, and evaluating their **chemical composition**. Below are the most commonly determined constants:

1. Acid Value

Definition:

The number of **milligrams of potassium hydroxide (KOH)** required to neutralize the **free fatty acids** present in **1 gram** of fat or oil.

Principle:

Free fatty acids in the fat are **titrated** with standard alcoholic **KOH** using **phenolphthalein** as an indicator.

Formula:

Acid Value = $\frac{\text{Volume of KOH (ml)} \times \text{Normality of KOH} \times 56.1}{\text{Weight of sample (g)}}$

Acid Value = $\frac{\text{Volume of KOH (ml)} \times \text{Normality of KOH} \times 56.1}{\text{Weight of sample (g)}}$

Significance:

- Indicates **hydrolytic rancidity**.
- Higher acid value = **poor quality** or **degraded** oil.
- Important in **food, cosmetics, and pharmaceuticals**.

2. Saponification Value

Definition:

The number of **milligrams of KOH** required to **saponify 1 gram** of fat or oil.

Principle:

Fat is **boiled with excess alcoholic KOH**, and the remaining unreacted KOH is titrated with **standard HCl**.

Formula:

$$\text{Saponification Value} = \frac{(B - S) \times N \times 56.1}{\text{Weight of sample (g)}}$$
$$\text{Saponification Value} = \text{Weight of sample (g)} \times (B - S) \times N \times 56.1$$

Where:

- B = Volume of HCl for blank
- S = Volume of HCl for sample
- N = Normality of HCl

Significance:

- Inversely related to **average molecular weight** of fatty acids.
- High saponification value = **short-chain fatty acids**.
- Helps in detecting **adulteration** and identifying **type of oil**.

3. Ester Value

Definition:

The difference between the **saponification value** and the **acid value**.

$$\text{Ester Value} = \text{Saponification Value} - \text{Acid Value}$$
$$\text{Ester Value} = \text{Saponification Value} - \text{Acid Value}$$

Significance:

- Represents the amount of **esterified (combined) fatty acids**.
- Helps differentiate **free and bound fatty acids**.
- Important in **perfumes, cosmetics, and flavor** industries.

4. Iodine Value

Definition:

The number of **grams of iodine** absorbed by **100 grams** of fat or oil.

Principle:

Iodine reacts with **double bonds (C=C)** in unsaturated fatty acids. Unreacted iodine is titrated with **sodium thiosulfate**.

Method Used:

- **Wijs method** or **Hanus method**

Formula:

$$\text{Iodine Value} = \frac{(B - S) \times N \times 12.69}{\text{Weight of sample (g)}}$$
$$\text{Iodine Value} = \frac{(B - S) \times N \times 12.69}{\text{Weight of sample (g)}}$$

Significance:

- Indicates **degree of unsaturation**.
- Higher iodine value = more **unsaturation** = **less stability**.
- Used in **soap, paint, and food** industries.

5. Acetyl Value

Definition:

The number of **milligrams of KOH** required to neutralize the acetic acid liberated from **1 gram of acetylated fat or oil**.

Principle:

Hydroxyl-containing oils are **acetylated** using **acetic anhydride**, then hydrolyzed to release **acetic acid**, which is titrated.

Significance:

- Measures the **hydroxyl group content** in the fat.
- Helps in identifying **castor oil, ricinoleic acid** derivatives.
- Important in **industrial and medicinal** oil characterization.

6. Reichert–Meissl (RM) Value

Definition:

The number of **milliliters of 0.1 N KOH** required to neutralize the **volatile water-soluble fatty acids** distilled from **5 grams** of fat.

Principle:

Fat is **saponified**, **acidified**, and the volatile fatty acids (like butyric and caproic acid) are **distilled off**, and titrated.

Significance:

- Indicates the presence of **short-chain fatty acids**.
- Used to detect **adulteration** in **butter**, **ghee**, and **milk fats**.
- Butter has a **high RM value** (~28), whereas vegetable oils have **low or zero**.

Summary Table

Constant	Definition	Significance
Acid Value	mg KOH to neutralize FFA in 1 g fat	Indicates free fatty acids; used to detect rancidity
Saponification Value	mg KOH to saponify 1 g fat	Inverse of average fatty acid chain length
Ester Value	SV – AV	Represents combined (esterified) fatty acids
Iodine Value	g I ₂ absorbed by 100 g fat	Measures degree of unsaturation
Acetyl Value	mg KOH to neutralize acetic acid from 1 g acetylated fat	Indicates hydroxyl group content
RM Value	ml of 0.1 N KOH for volatile fatty acids from 5 g fat	Identifies milk fats and detects adulteration in butter



Conclusion

Analytical constants are essential **quality control parameters** for oils and fats. They provide information about:

- The **type and purity** of the oil
- Its **chemical stability** and **suitability** for consumption or industrial use
- Its **functional groups**, **chain lengths**, and **degree of saturation**

They are critical in **pharmaceutical formulations**, **food quality standards**, **cosmetics**, and **forensic analysis of adulteration**.

CHAPTER-11

TOPIC- Polynuclear hydrocarbons:
Synthesis, reactions

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Polynuclear Hydrocarbons: Synthesis and Reactions

1. Introduction

Polynuclear hydrocarbons (also known as **polycyclic aromatic hydrocarbons** or **PAHs**) are organic compounds consisting of **two or more fused aromatic rings**. These compounds are found in **coal tar, tobacco smoke, grilled foods**, and are also formed during **incomplete combustion** of organic matter.

Examples:

- **Naphthalene** (2 rings)
- **Anthracene** (3 linear rings)
- **Phenanthrene** (3 angular rings)
- **Chrysene, Benzo[a]pyrene, Pyrene** (4 or more rings)

2. Classification

Type	Structure Example	Formula
Bicyclic Aromatic	Naphthalene	$C_{10}H_8$
Tricyclic Aromatic	Anthracene, Phenanthrene	$C_{14}H_{10}$
Tetracyclic and Higher	Benzo[a]pyrene	$C_{20}H_{12}$

3. General Properties

- **Planar, conjugated π -systems**
- **Highly stable** due to resonance
- **Hydrophobic** and often volatile
- Most are **toxic and carcinogenic** (especially benzo[a]pyrene)

4. Synthesis of Polynuclear Hydrocarbons

4.1 Naphthalene Synthesis

a) From Coal Tar:

- Naphthalene is naturally present in the **light oil fraction** of coal tar (~10%).

b) Haworth Synthesis:

Used for synthesizing substituted naphthalenes.

4.2 Anthracene and Phenanthrene

a) From Coal Tar:

- Obtained by fractional crystallization from the **green oil fraction** of coal tar.

b) Haworth Synthesis (for Phenanthrene):

A multi-step synthetic method involving Friedel–Crafts acylation, cyclization, and reduction.

4.3 Benzo[a]pyrene and Higher PAHs

- Synthesized via **multiple Friedel–Crafts reactions** or **cyclodehydrogenation** methods.

5. Reactions of Polynuclear Hydrocarbons

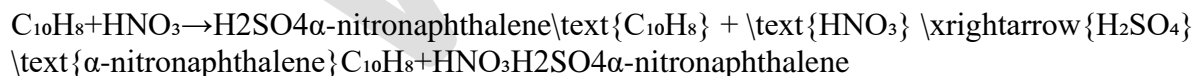
Most reactions involve **electrophilic substitution** and **oxidation**, reflecting their aromatic character.

5.1 Electrophilic Substitution Reactions (EAS)

Like benzene, PAHs undergo:

- **Nitration**
- **Sulphonation**
- **Halogenation**
- **Friedel–Crafts reactions**

Example: Nitration of Naphthalene



- **Alpha (1-) position** is more reactive than beta (2-) in naphthalene.
- Substitution occurs preferentially at the **most electron-rich ring** in phenanthrene or anthracene.

5.2 Oxidation Reactions

a) Mild Oxidation:

- Oxidation of side chains or certain rings.
- E.g., anthracene → anthraquinone (important dye intermediate)

b) Severe Oxidation:

- Complete breakdown to **phthalic acid**, CO₂, and **water**

5.3 Reduction Reactions

a) Catalytic Hydrogenation:

- Converts PAHs to **tetralin** (naphthalene → decalin)
- Industrial use in **lubricants and fuels**

b) Chemical Reduction:

- Lithium or sodium in alcohol can partially reduce PAHs (e.g., naphthalene → 1,4-dihydronaphthalene)

5.4 Addition Reactions

At high temperatures and pressures:

- Unsaturated systems can undergo **hydrogenation** or **Diels-Alder additions** with dienophiles.

6. Applications

Polynuclear Hydrocarbon	Application
Naphthalene	Mothballs, synthetic dyes, phthalic anhydride
Anthracene	Dyes (alizarin), UV detector coatings
Phenanthrene	Intermediate for hormones, alkaloids
Benzo[a]pyrene	Studied as a potent carcinogen in environmental toxicology

7. Toxicity and Health Hazards

Many PAHs are:

- **Mutagenic**
- **Carcinogenic**
- **Bioaccumulative**

Source of Exposure:

- Grilled meat, vehicle exhaust, cigarette smoke, coal tar

Example: Benzo[a]pyrene

- Activated by liver enzymes → **epoxides** → bind to DNA → mutations → **cancer**

Summary

Property	Polynuclear Hydrocarbons
Structure	2+ fused aromatic rings
Stability	High, due to extended conjugation
Reactions	Electrophilic substitution, oxidation, reduction
Sources	Coal tar, combustion processes
Uses	Dyes, pesticides, pharmaceuticals
Hazards	Carcinogenic, environmental pollutants

CHAPTER-12

TOPIC- Structure and medicinal uses of Naphthalene, Phenanthrene, Anthracene, Diphenylmethane, Triphenylmethane and their derivatives

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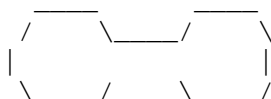
Structure and Medicinal Uses of Naphthalene, Phenanthrene, Anthracene, Diphenylmethane, and Triphenylmethane

1. Naphthalene

Structure:

- Consists of two **fused benzene rings** in a linear arrangement.
- **Molecular formula:** $C_{10}H_8$

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Medicinal and Other Uses:

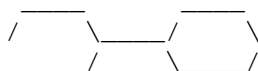
- **Antiseptic:** Used in older antiseptic powders and dusting agents.
- **Moth repellent:** Active ingredient in **mothballs**.
- Precursor for **phthalic anhydride**, which is used in drug and dye synthesis.
- Derivatives such as **naphthoquinones** have **antimicrobial** and **anticancer** potential.

2. Phenanthrene

Structure:

- Consists of three **fused benzene rings** arranged in an angular (non-linear) fashion.
- **Molecular formula:** $C_{14}H_{10}$

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Medicinal and Biological Uses:

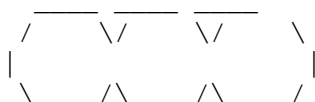
- Phenanthrene is a core nucleus in **steroids** and **bile acids**.
- Used in synthesis of **estrogenic compounds**, **hormones**, and **alkaloids**.
- Derivatives are explored in **anti-inflammatory**, **antioxidant**, and **anticancer** drug development.
- Also used in the development of **analgesics** and **antipyretics**.

3. Anthracene

Structure:

- Composed of three **linearly fused benzene rings**.
- **Molecular formula:** $C_{14}H_{10}$

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Medicinal and Industrial Uses:

- Used as a precursor to **anthraquinone**, an intermediate in the manufacture of **laxatives** (e.g., **danthron**, **aloin**, **emodin**).
- Basis for **anti-parasitic** and **antimicrobial** agents.
- Employed in **photovoltaic** and **fluorescent** materials for medical imaging.

4. Diphenylmethane

Structure:

- Consists of two **benzene rings** linked by a **methylene (-CH₂-) bridge**.
- **Molecular formula:** $C_{13}H_{12}$

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Where Ph = Phenyl group (C_6H_5)

Medicinal Uses:

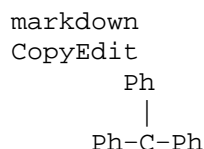
- Structural core in **first-generation antihistamines** like **diphenhydramine** (Benadryl).
- Found in **antitussives**, **sedatives**, and **antiemetics**.
- Used in drugs that act on the **CNS**, especially **anticholinergic** agents.
- Derivatives include:

- **Diphenhydramine:** Antihistamine with sedative effect
- **Orphenadrine:** Used for muscle spasms and Parkinsonism

5. Triphenylmethane

Structure:

- Consists of a central **methane carbon** bonded to **three phenyl groups**.
- **Molecular formula:** $C_{19}H_{16}$



Medicinal and Industrial Uses:

- Parent structure of **triphenylmethane dyes**: brilliant green, malachite green, crystal violet.
- Some dyes have **antibacterial** and **antifungal** properties and are used in:
 - **Antiseptic preparations**
 - **Wound disinfectants**
- Used to develop agents with **DNA-intercalating** properties (potential anticancer agents).
- Structural basis for **histological staining** in pathology labs.

Important Derivatives and Their Applications

Core Compound	Derivative	Use/Activity
Naphthalene	Naphthoquinone	Anticancer, antimalarial (e.g., atovaquone)
Phenanthrene	Estrone, Estradiol	Estrogenic hormones
Anthracene	Danthron, Aloin	Laxatives, anti-constipation agents
Diphenylmethane	Diphenhydramine	Antihistamine, sedative
Triphenylmethane	Crystal violet, Malachite green	Antiseptic dyes, DNA stains

Summary Table

Compound	Structure	Major Uses
Naphthalene	Two fused benzene rings	Mothballs, antiseptics, dye intermediates
Phenanthrene	Angular tricyclic aromatic	Hormone synthesis, anti-inflammatory drug base
Anthracene	Linear tricyclic aromatic	Laxatives, dye synthesis, photoconductors
Diphenylmethane	Two phenyl groups linked by	CNS drugs, antihistamines, antispasmodics

Compound	Structure	Major Uses
Triphenylmethane	Three phenyls on one central C CH_2	Antiseptics, dyes, potential anticancer agents



Conclusion

The hydrocarbon scaffolds of **naphthalene**, **phenanthrene**, **anthracene**, **diphenylmethane**, and **triphenylmethane** serve as important **chemical backbones** in the development of numerous **therapeutic agents** and **industrial dyes**. Their derivatives are widely used in **antihistamines**, **hormone therapies**, **laxatives**, and **antiseptic preparations**.

CHAPTER-13

TOPIC- Cyclo alkanes*

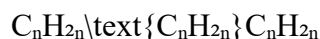
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VBSRU

Cycloalkanes

1. Introduction

Cycloalkanes are a class of **saturated hydrocarbons** where the carbon atoms are arranged in a **closed ring**. They contain only **single bonds (σ bonds)** between carbon atoms and follow the general molecular formula:



They are also known as **naphthenes** (especially in petroleum chemistry) and are considered **alicyclic compounds** because they exhibit properties of both **alkanes** and **cyclic structures**.

2. General Formula and Examples

Cycloalkane	Formula	Structure
Cyclopropane	C_3H_6	Triangle ring
Cyclobutane	C_4H_8	Square ring
Cyclopentane	C_5H_{10}	Pentagon ring
Cyclohexane	C_6H_{12}	Hexagonal ring

3. Nomenclature

Cycloalkanes are named by:

- Adding the prefix **“cyclo”** to the name of the corresponding alkane.
- Substituents are named and numbered to give the **lowest possible numbers**.

Examples:

- Methylcyclopentane** (a methyl group on a cyclopentane ring)
- 1,2-Dimethylcyclobutane**

4. Structure and Bond Angles

Cycloalkanes differ in **ring size**, which affects their **bond angles** and **stability**:

Ring	Ideal Angle (sp^3)	Actual Bond Angle	Strain
Cyclopropane	109.5°	$\sim 60^\circ$	High (angle strain)
Cyclobutane	109.5°	$\sim 90^\circ$	Moderate strain

Ring	Ideal Angle (sp ³)	Actual Bond Angle	Strain
Cyclopentane	109.5°	~108°	Low strain
Cyclohexane	109.5°	~109.5° (chair form)	Minimal strain

Types of Strain:

- **Angle strain:** Deviation from ideal tetrahedral angle
- **Torsional strain:** Due to eclipsing interactions
- **Steric strain:** Due to repulsion between bulky groups

5. Conformations of Cycloalkanes

Cyclohexane:

- Exists in **chair**, **boat**, and **twist-boat** conformations.
- **Chair conformation** is the most stable, minimizing angle and torsional strain.

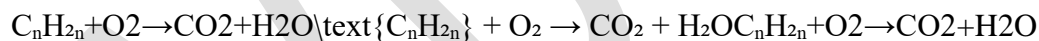
Cyclopentane:

- Adopts an **envelope** conformation to reduce torsional strain.

6. Chemical Properties

Cycloalkanes are relatively **less reactive** than alkenes and alkynes but undergo:

a) Combustion:



- Used in energy generation from petroleum.

b) Substitution Reactions:

- Undergo **halogenation** in the presence of UV light (like alkanes).

c) Ring-opening Reactions:

- Small rings (cyclopropane, cyclobutane) are **reactive due to strain** and can undergo ring-opening reactions with nucleophiles.

7. Laboratory and Industrial Importance

- Cycloalkanes are major components of **petroleum** and **natural gas**.

- Used as **intermediates** in chemical synthesis.
- **Cyclohexane** is used in the production of **nylon** (via **adipic acid** and **caprolactam**).
- **Cyclopropane** has historical use as a **gaseous anesthetic**.

8. Comparison with Alkanes and Alkenes

Property	Cycloalkanes	Alkanes	Alkenes
Formula	C_nH_{2n}	C_nH_{2n+2}	C_nH_{2n}
Reactivity	Low	Low	High
Type of Bond	Single (ring)	Single	Double
Isomerism	Geometrical possible	Not possible	Geometrical

Summary

- Cycloalkanes are **saturated cyclic hydrocarbons** with formula C_nH_{2n} .
- Stability depends on **ring size** and **conformation**.
- Undergo **combustion**, **substitution**, and **ring-opening** reactions.
- Widely used in **industrial chemistry**, **petrochemicals**, and **organic synthesis**.