Organic chemistry

(Dr. Rana Akram)

Organic chemistry is the study of carbon and the **study of the chemistry of life**. Since not all carbon reactions are organic, another way to look at organic chemistry would be to consider it the **study of molecules** containing the carbon-hydrogen (C-H) bond and their reactions.

Methane, CH\(_4\), is the simplest organic molecule. It is a gas at **standard temperature and pressure** and is a carbon atom with four hydrogen atoms bonded to it in a tetrahedral shape.
Why Is Organic Chemistry Important?

Organic chemistry is important because it is the study of life and all of the chemical reactions related to life. Several careers apply an understanding of organic chemistry, such as doctors, veterinarians, dentists, pharmacologists, chemical engineers, and chemists. Organic chemistry plays a part in the development of common household chemicals, foods, plastics, drugs, fuels... really most of the chemicals part of dail

chemical bonds:
Chemical bonding describes a variety of interactions that hold atoms together in chemical compounds

**Types of chemical bond:**

1. Ionic or electrovalent bond- due to transfer of electrons, the electrostatic force is developed between positive and negative ion. Thus an electrovalent bond is formed. ex. Na + Cl $\rightarrow$ Na$^+$ + Cl$^-$ $\rightarrow$ NaCl

2. Covalent or molecular bond-Bond formed between two atoms by sharing of electrons equally.

   - A covalent bond can be of two types:
     - Polar Bond like HCl
     - Non-polar Bond
   - In a Polar bond, electrons are shared unequally and they tend to be closer to one atom than the other.
   - Due to this uneven distance between the electron and atom, there is charge difference created in the different parts of the atom.
• One end of the molecule will be slightly positively charged and one end slightly negatively charged.
• Water is an example of a polar molecule.

3. Non polar covalent bond - When the constituting atoms have slight or no difference in their electronegativities, they form non polar covalent type of bond.

4. Coordinate or dative bonds - The chemical bond between two atoms in which a pair of electrons belonging to one of them is shared by both the atoms

\[
\begin{align*}
\text{example} & \\
H & \quad \text{N} \quad H & + [H]^{+} & \rightarrow H \quad \text{N} \quad H \\
& & & & \\
H - \text{N} - H & + [H]^{+} & \rightarrow H - \text{N} - H
\end{align*}
\]
Hydrogen Bonds

Hydrogen-bonding occurs when an atom of hydrogen is attracted by rather strong forces to two (groups of) atoms instead of only one, such that it may be considered to be acting as a bond between them.

![Hydrogen bond diagram](image)

Electron Configuration and Valence Electrons

Electron Configuration

The electrons in an atom fill up its atomic orbitals according to the Aufbau Principle; "Aufbau," in German, means "building up." The Aufbau Principle, which incorporates the Pauli Exclusion Principle and Hund's Rule prescribes a few simple rules to determine the order in which electrons fill atomic orbitals:

1. Electrons always fill orbitals of lower energy first. $1s$ is filled before $2s$, and $2s$ before $2p$.
2. The Pauli Exclusion Principle states no two electrons within a particular atom can have identical quantum numbers. In function, this principle means that if two electrons occupy the same orbital, they must have opposite spin.
1. Electrons always fill orbitals of lower energy first. $1s$ is filled before $2s$, and $2s$ before $2p$.

2. The Pauli Exclusion Principle states no two electrons within a particular atom can have identical quantum numbers. In function, this principle means that if two electrons occupy the same orbital, they must have opposite spin.

3. Hund’s Rule states that when an electron joins an atom and has to choose between two or more orbitals of the same energy, the electron will prefer to enter an empty orbital rather than one already occupied. As more electrons are added to the atom, these electrons tend to half-fill orbitals of the same energy before pairing with existing electrons to fill orbitals.

Hund’s Rule:
Electrons occupy separate orbitals rather than pair.
<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Element Symbol</th>
<th>Electron Configuration</th>
<th>Number of Valence Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>1s(^1)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>He</td>
<td>1s(^2)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Li</td>
<td>1s(^2)2s(^1)</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Be</td>
<td>1s(^2)2s(^2)</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>1s(^2)2s(^2)2p(^1)</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>1s(^2)2s(^2)2p(^2)</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>N</td>
<td>1s(^2)2s(^2)2p(^3)</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>O</td>
<td>1s(^2)2s(^2)2p(^4)</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>1s(^2)2s(^2)2p(^5)</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>Ne</td>
<td>1s(^2)2s(^2)2p(^6)</td>
<td>8</td>
</tr>
</tbody>
</table>
Hybridization

Hybridization is the idea that atomic orbitals fuse to form newly hybridized orbitals, which in turn, influences molecular geometry and bonding properties. Hybridization is also an expansion of the valence bond theory. In order to explore this idea further, we will utilize three types of hydrocarbon compounds to illustrate $sp^3$, $sp^2$, and $sp$ hybridization.

Methane

first and foremost, it is important to note that carbon has the electron configuration of $1s^2\ 2s^2\ 2p^2$. This means that carbon would have 2 unpaired electrons in its p orbitals. Theoretically, this means that carbon will only form 2 bonds, but that is definitely not the case.

As seen in methane (CH$_4$), carbon can form 4 bonds. The rationale behind this phenomenon is hybridization. Supporting evidence shows that 1 s and 3 p orbitals are being combined to form hybrid orbitals, allowing polyatomic molecule to have 25% s character and 75% p character. Thus, we call methane a $sp^3$-hybridized molecule.

![Diagram of hybridization](image)
Ethylene

Unlike methane, ethylene is shaped differently, despite the fact that the carbon in ethylene has the same electron configuration. What accounts for this difference? Supporting evidence shows that the carbon in an ethylene molecule is sp\(^2\) hybridized. This means that 1 s orbital is being mixed with 2 p orbitals.

\[\text{C} \quad 1s^2 2s^2 2p^2\]

The energy diagram setup is different because only 2 p orbitals are being mixed. While creating your energy diagram, however, be sure that you do not make the mistake as shown above. By placing two electrons in the same orbital, you have broken **Hund’s rule**, which states that all orbitals among the same energy levels have to be filled with at least one electron before being paired up again. The 2p orbital here is considered low enough energy to be classified within the same energy level as the sp\(^2\) orbitals. The figure below portrays the correct way to distribute your electrons.
Notice how that lone electron in the 2p orbital is separate from the electrons in the sp2 orbitals. This is what influence ethylene’s shape. The lone electron from each carbon will remain in its respective p orbital and form a pi bond with the other p orbital electron. Thus, ethylene is a planar molecule, with orbitals spaced 120 degree angles apart.
**Acetylene**

supporting evidence shows that acetylene is an sp molecule. This means that 1 s orbital is being mixed with 1 p orbital. Thus, the energy diagram setup would look like this:

\[
C \quad 1s^22s^22p^2
\]

![Energy diagram for acetylene](image)
C \(1s^2 2s^2 2p^2\)
reviously discussed, the lone electrons in the 2p orbitals are not part of the sp orbitals. Instead, each electron is in its respective p orbital, and will bond with its respective p orbital of the other carbon. This in itself will create a sigma bond and two pi bonds, leading to the formation of a linear molecule!

Thus, in a lewis structure, acetylene is comprised of 2 triple-bond carbons:

As you can see, the bond angle is 180 degrees, indicative of a linear molecule. This information is consistent with what was explained earlier.

HOME WORK?

1- Types of chemical bonds?
2- Types of Hybridization
STRUCTURAL ISOMERISM

What is structural isomerism?

What are isomers?

Isomers are molecules that have the same molecular formula, but have a different arrangement of the atoms in space.
Structural isomerism is of five types:

1. Chain isomerism
2. Position isomerism
3. Functional group isomerism
4. Metamerism
5. Tautomerism

1. Chain isomerism

Chain isomerism is a type of structural isomerism where the isomers have same molecular formula but they differ in the order in which the carbon atoms are bonded to each other. Thus the isomers arise with different types of branching in carbon chains. For example, Pentane, C₅H₁₂, has three chain isomers. These are n-pentane, isopentane and neopentane.

\[
\begin{align*}
\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3 & \quad \text{pentane} \\
& \quad (n\text{-pentane}) \\
\text{CH}_3\text{-CH}\text{-CH}_2\text{-CH}_3 & \quad \text{methylbutane} \\
& \quad (\text{isopentane}) \\
\text{CH}_3\text{-C}\text{-CH}_3 & \quad \text{dimethylpropane} \\
& \quad (\text{neopentane})
\end{align*}
\]

2. Position isomerism

Position isomerism is a type of structural isomerism where the main carbon skeleton are same but they differ in the position of functional group attached to it. For example, there are two structural isomers occurs in n-butanol with the molecular formula C₄H₉OH. In one of them the functional group -OH is on the end of the chain, whereas in the other it is attached to the second carbon of the main carbon chain.
3. Functional group isomerism

Functional group isomerism is a type of structural isomerism where isomers have the same molecular formula but differ in functional group. Thus, they belong to different families of compounds or different homologous series. For example, there are two functional group isomers found with the molecular formula $C_2H_6O$. Ethanol and dimethyl ether are those two functional group isomers. Here, ethanol contains alcohol as functional group and dimethyl ether contains ether.

![Structural formulas of ethanol and dimethyl ether]
A hydrocarbon is an organic compound made of nothing more than carbons and hydrogen. It is possible for double or triple bonds to form between carbon atoms and even for structures, such as rings, to form.

Hydrocarbons that have 4 bonds to every carbon atom are called alkanes. These are the least reactive of the hydrocarbons.

Hydrocarbons that have a double bond between two carbon atoms are called alkenes. These are more reactive than alkanes. Electron-poor molecules react at the pi bond of alkenes.

Hydrocarbons that have a triple bond between two carbon atoms are called alkynes. These are the most reactive. Electron-poor molecules react at the pi bond of alkynes.
C atoms

1  meth
2  eth
3  prop
4  but
5  pent
6  hex
7  hept
8  oct
9  non
10 dec

+ ane
  or
  ene
  or
  yne
Properties of Alkanes

(a) State:

(i) All are colourless & possess no characteristic odour.

(ii) Lower alkanes (C₁ to C₄) are gases, middle one (C₃ to C₁₇) are liquids and higher are solids.

(iii) The boiling point of alkanes increases with increase in molecular weight due to increase in van der waals forces with increase in molecular weight i.e.,

(iv) Also the branching in alkanes gives a decrease in surface area (as the shape approaches to spherical) which results in decrease in van der Waals forces. That is why b.pt. of isomeric alkanes who the order : pentane > isopentane > neopentane

(v) The melting points of alkanes do not show a regular trend. Alkanes with even number of carbon atoms have higher m.pt. than their adjacent of odd number of carbon atoms.

(b) Density
The density of alkanes increases with increase in molecular weight and becomes constant at 0.76 g/ml. Thus all alkanes are lighter than water.

(c) Solubility :

(i) Alkanes being non polar and thus insoluble in water but soluble in non polar solvents e.g., C₆H₆, CCl₄, ether etc.

(ii) The solubility of alkanes decreases with increase in molecular weight.

(iii) Liquid alkanes are themselves good, non polar solvents.
Preparation of Alkanes:
FROM ALKYL HALIDES (By Wurtz Reaction)

\[
2 \text{R} - X + 2 \text{Na} \xrightarrow{\text{Dry ether}} \text{R} - \text{R} + 2 \text{NaX}
\]

For example,
\[
2 \text{CH}_3\text{I} + 2 \text{Na} \xrightarrow{\text{Dry ether}} \text{CH}_3\text{CH}_3 + 2 \text{NaI}
\]
Methyl iodide

\[
2 \text{CH}_3\text{CH} = \text{CH}_2 + 2 \text{Na} \xrightarrow{\text{Dry ether}} \text{CH}_3\text{CH} - \text{CH} - \text{CH}_3 + 2 \text{NaI}
\]

FROM UNSATURATED HYDROCARBONS:

\[
\text{CH}_2 = \text{CH}_2 + \text{H}_2 \xrightarrow{\text{Ni}\ 523 - 573\ K} \text{CH}_3 - \text{CH}_3
\]
Ethene

\[
\text{CH} = \text{CH} + 2 \text{H}_2 \xrightarrow{\text{Ni}\ 523 - 573\ K} \text{CH}_3 - \text{CH}_3
\]
Ethyne
Reactions of Alkanes

1- Combustion of Alkanes. Alkanes burn in air at elevated temperatures to carbon dioxide and water

2- HALOGENATION
The Mechanism of Halogenation steps: initiation, propagation and termination

Step 1: Initiation

\[ \text{Cl-Cl} \rightarrow \cdot \text{Cl} + \cdot \text{Cl} \]

Step 2: Propagation
Pharmaceutical uses of alkane?
The pharmaceutical use of alkane is often used in general anesthesia. Alkane is a compound of halothane which is a general anesthetic agent?

\[ \text{mechanism of free radical of H.W} \] (Halogenation of alkane)?
Alkenes: Structures and Names:

Alkenes are hydrocarbons with carbon-to-carbon double bonds (R₂C=CR₂). The alkenes are another group of hydrocarbons that forms a homologous series where all members conform to the general molecular formula CₙH₂ₙ.

Structure of Alkenes

In alkenes, carbon atoms which form the double bonds use sp² hybridization. I.e., the one 2s orbital is mixed with two of the three 2p orbitals to form three atomic orbitals of equal energies.

One of the 2p orbitals is unhybridized.

The simplest hydrocarbon carbon can form with this type of hybridization is one having two carbon atoms with the same type of hybridization - sp².

The three hybridized orbitals are used to form real bonds known as sigma (σ) bonds - one with the adjacent carbon atom (sp²- sp²), and the other two separately with the s orbital of two hydrogen atoms (in ethene).

The unhybridized 2p orbitals of the two atoms overlap with each other to form a kind of bond called pi (π) bond - the presence of this bond (electrons in a plane above and below the single bond) gives rise to the unsaturability in alkenes.

orbital diagram in ethene:
Ethene is the simplest and the most important member of the alkenes. It is used in illustrating the structure, methods of preparation and chemical reactions of members of the group. The structure of ethene is again given below.

Ethene is trigonal planar in shape, with bond angle $120^\circ$.

**Preparation of Alkenes:**
1-By the elimination of halogen and hydrogen (dehydrohalogenation) -

$$
\text{CH}_3\text{CH}_2\text{Cl} \xrightarrow{\text{KOH}, \text{C}_2\text{H}_5\text{OH}} \text{CH}_2=\text{CH}_2 \quad \text{Ethene}
$$

From secondary alkyl halides:

$$
\text{CH}_3\text{CH}_2\text{CHCH}_3 \xrightarrow{\text{KOH}, \text{C}_2\text{H}_5\text{OH}} \text{CH}_3\text{CH}=\text{CHCH}_3 + \text{CH}_3\text{CH}_2\text{CH}=\text{Cl} \quad \text{Internal alkene} \quad \text{Terminal alkene}
$$
Mechanism of reaction:

\[
\text{CH}_3\text{-C-C-CH}_3 \rightarrow \text{CH}_3\text{-C=C-CH}_3
\]

Internal alkene

and

\[
\text{CH}_3\text{-C-C-C-H} \rightarrow \text{CH}_3\text{-C-C=CH}_2
\]

Terminal alkene
2. By elimination of halogen (dehalogenation)

\[
\text{CH}_2\text{CHClCH}_2\text{Cl} \xrightarrow{\text{Zn, Heat}} \text{CH}_3\text{CH}==\text{CH}_2 + \text{ZnCl}_2
\]

Physical properties:
1. It is a gas at room temperature, colorless and with a faint sweetish smell.
2. Almost insoluble in water.
3. Slightly less dense than air (v.d. = 14).
4. Neutral to litmus.

**Common Addition Reactions of Alkenes**

1. Hydrogenation of Alkenes

\[
\text{CH}_2=\text{CH}_2 + \text{H}_2 \xrightarrow{\text{Ni (150°C)}} \text{CH}_3\text{CH}_3
\]

2. Alkenes with Bromine

\[
\text{H}_2\text{C} = \text{CH}_2(\text{g}) + \text{Br}_2(\text{l}) \rightarrow \text{CH}_2\text{Br} - \text{CH}_2\text{Br}(\text{l})
\]
3. Alkenes with Concentrated Sulphuric Acid

\[
\begin{align*}
\text{CH}_2=\text{CH} + \text{H}_2\text{SO}_4 & \xrightarrow{\text{heat}} \text{CH}_3\text{CH}_2\text{OSO}_2\text{OH} \\
\text{CH}_3\text{CH}_2\text{OSO}_2\text{OH} + \text{H}_2\text{O} & \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{SO}_4
\end{align*}
\]

4. Alkenes with Hydrogen Halide

\[
\text{CH}_2=\text{CH} + \text{HX} \rightarrow \text{CH}_3\text{CH}_2\text{X}
\]

**Nomenclature of Alkenes**

**International Union of Pure and Applied Chemistry (IUPAC):**

1. The longest chain of carbon atoms containing the double bond is considered the parent chain. It is named using the same stem as the alkane having the same number of carbon atoms but ends in -ene to identify it as an alkene. Thus the compound \( \text{CH}_2=\text{CHCH}_3 \) is propene.

2. If there are four or more carbon atoms in a chain, we must indicate the position of the double bond. The carbons atoms are numbered so that the first of the two that are doubly bonded is given the lower of the two possible numbers. The compound \( \text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_3 \), for example, has the double bond between the second and third carbon atoms. Its name is 2-pentene (not 3-pentene).
3. Substituent groups are named as with alkanes, and their position is indicated by a number. Thus,

**Draw the structure for each compound.**

1. 3-methyl-2-pentene
2. cyclohexene

\[
\text{CH}_3-\text{CH} \equiv \text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3
\]

1-pentene or pent-1-ene

\[
\text{CH}_3-\text{CH}_2-\text{C} \equiv \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3
\]

2-ethyl-1-hexene or 2-ethylhex-1-en

\[
\text{CH}_3-\text{CH} \equiv \text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3
\]

3-heptene
**Alkyne:**

3D model of ethyne (acetylene), the simplest alkyne

In *organic chemistry*, an alkyne is an unsaturated hydrocarbon containing at least one carbon—carbon *triple bond*.\(^1\) The simplest acyclic alkynes with only one triple bond and no other *functional groups* form a *homologous series* with the general chemical formula \(\text{C}_n\text{H}_{2n-2}\).

**Chemical properties:**

Alkynes are in gaseous form and they are soluble in organic solvents, like benzene and acetone. They are, however, insoluble in water. Another property of an alkyne is that, if you try to burn it,
Ethyne \[ \text{H} - \text{C} \equiv \text{C} - \text{H} \]

Propyne \[ \text{H} - \text{C} \equiv \text{C} - \text{C} - \text{H} \]

Butyne \[ \text{H} - \text{C} - \text{C} \equiv \text{C} - \text{C} - \text{H} \]

EXAMPLE S??
Methods of Preparation of Alkynes:

1. By the Action of Calcium Carbide and Water

\[
\text{CaC}_2 + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{C}_2\text{H}_2
\]

Calcium carbide

2. Dehydrohalogenation of Dihalides

\[
\text{BrCH}_2 \text{CH}_2\text{Br} + 2\text{KOH} \text{(alc)} \rightarrow \text{HC} = \text{CH} + 2\text{KBr} + 2\text{H}_2\text{O}
\]

1, 2-Dibromoethane

3. Formation of Higher Alkynes from Acetylene

\[
\text{HC} \equiv \text{CH} + \text{NaNH}_2 \rightarrow \text{HC} \equiv \text{CNa} + \text{NH}_3
\]

Sodamide

\[
2\text{HC} \equiv \text{CH} + 2\text{Na} \rightarrow 2\text{HC} \equiv \text{CNa}^+ + \text{H}_2
\]

Sodium ethynide
Preparation of Alkynes

Dihaloalkane Elimination

\[ \text{R}^\prime \text{-C-C-R} + 2\text{B}^\text{-} \rightarrow \text{R}^\prime \text{C}≡\text{C-R} \]

or

\[ \text{H} \text{-X} \text{-X} \text{H} \text{-X} \text{-X} \text{H} \text{H} \rightarrow \text{R}^\prime \text{C}≡\text{C-R} \]

the Mechanism:

\[ \text{CH}_3\text{CH}_2\text{-C-C-C-CH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{-C}≡\text{C-CH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{C}≡\text{C-CH}_3 \]

\[ \begin{array}{c}
\text{Br}^-
\
\text{NaNH}_2
\end{array} \quad \begin{array}{c}
\text{Br}^-
\
\text{Br}^-
\end{array} \quad \begin{array}{c}
\text{Br}^-
\
\text{Br}^-
\end{array} \]
Cycloalkanes are cyclic hydrocarbons, meaning that the carbons of the molecule are arranged in the form of a ring.

Rules for Naming Cycloalkanes

Cycloalkanes are ring structures with the general formula: $C_nH_{(2n)}$. Following are basic rules for naming cycloalkanes.

1. Parent Chain

   a. Use the cycloalkane as the parent chain if it has a greater number of carbons than any alkyl substituent.
   b. If an alkyl chain off the cycloalkane has a greater number of carbons, then use the alkyl chain as the parent and the cycloalkane as a cycloalkyl-substituent.
2. Numbering the Cycloalkane

   a. When numbering the carbons of a cycloalkane, start with a substituted carbon so that the substituted carbons have the lowest numbers (sum).
   b. When two or more different substituents are present, number according to alphabetical order.

3. Halogen Substituents

   a. Halogen substituents are treated exactly like alkyl groups

**Cycloalkanes: Physical Properties**

Cyclopropane and cyclobutane are gases at room temperature while cyclopentane is already liquid at this temperature. Only van der Waals interactions play an important role in saturated hydrocarbons. Generally, alkanes are not very reactive. However, protonations, oxygenations, pyrolysis, radiolysis, and photolysis are possible under drastic conditions. Oxidation of alkanes can be carried out electrochemically. Lower cycloalkanes are especially flammable and form explosive mixtures with air (oxygen). Solubility in water is very low.
Synthesis of cyclo alkanes

Chemical Properties of Cycloalkanes

a) Free radical substitution: Cycloalkanes are halogenated in presence of sun light or UV light like alkane.
(b) Addition reactions: Cyclopropane being the most strained ring and more reactive undergoes addition reactions like alkenes.
c) Oxidation: Cycloalkanes are oxidized by alkaline potassium permanganate to dicarboxylic acids involving ring fusion.
Aromatic compound

Aromatic compound, any of a large class of unsaturated chemical compounds characterized by one or more planar rings of atoms joined by covalent bonds of two different kinds, like Benzene.
THE NAMES OF AROMATIC COMPOUNDS

The benzene ring:

All aromatic compounds are based on benzene, \( \text{C}_6\text{H}_6 \), which has a ring of six carbon atoms and has the symbol:

You get a phenyl group, \( \text{C}_6\text{H}_5 \), by removing a hydrogen from a benzene ring, \( \text{C}_6\text{H}_6 \). Like a methyl or an ethyl group, a phenyl group is always attached to something else

Aromatic compounds with only one group attached to the benzene ring

- Chlorobenzene
- Bromobenzene
- Iodobenzene
- Nitrobenzene
- Ethylbenzene
toluene  ortho-xylene  meta-xylene  para-xylene
methylbenzene  1,2-dimethylbenzene  1,3-dimethylbenzene  1,4-dimethylbenzene

NH₂  OH  H⁺  COOH
aniline  phenol  benzoic acid
aminobenzene  hydroxybenzene

Cl  Br  I
Chlorobenzene  Bromobenzene  Iodobenzene

CH₃  CH₃  CH₃
2-Chlorotoluene  3-Chlorotoluene  4-Chlorotoluene
(o-Chlorotoluene)  (m-Chlorotoluene)  (p-Chlorotoluene)
Which compounds are aromatic?

Polycyclic Aromatic Hydrocarbons

Naphthalene

Anthracene

Phenanthrene
Electrophilic Aromatic Substitution: Introduction

Quick summary: Electrophilic Aromatic Substitution

- Unlike alkenes, benzene + other aromatics do not generally undergo addition reactions.
- Addition of electrophiles (such as Cl₂) tends to result in substitution instead.
- These reactions are greatly facilitated by addition of a Lewis acid catalyst.
- Key reaction pattern is **electrophilic aromatic substitution**:

  \[
  \text{benzene (or other aromatic)} \xrightarrow{\text{Lewis Acid (catalyst)}} E \\
  \text{electrophilic aromatic substitution product}
  \]
The bromination of benzene

All electrophilic aromatic substitution reactions share a common mechanism. This mechanism consists of a series of steps.

- mechanism of Nitration of benzene and Sulfonation -???