

Family	Generic Pattern	Example	Saturated?
Alkane	$C_nH_{2n+2}$	Propane ( $C_3H_8$ )	Saturated
Alkene	$C_nH_{2n}$	Propene ( $C_3H_6$ )	Unsaturated
Alkyne	$C_nH_{2n-2}$	Propyne ( $C_3H_4$ )	Unsaturated
Cycloalkane	$C_nH_{2n}$	Cyclopropane ( $C_3H_6$ )	Saturated
Cycloalkene	$C_nH_{2n-2}$	N/A	N/A

- **Alkanes** have all single bonds and are saturated with hydrogen.

**Saturated:** Containing the greatest possible number of hydrogen atoms per molecule.

- **Alkenes** have a double bond; two fewer hydrogen atoms, and are unsaturated.
- **Alkynes** have a triple bond; four fewer hydrogen atoms than alkanes, and are unsaturated.
- **Cycloalkanes** have a single bond in a circle. For cycloalkanes, making the ring "pops out" some hydrogens.
- **Cycloalkenes** have a double bond in a ring.

## Using Generic Formulas

Given a molecular formula, you can determine which family it belongs to.

- Example:  $C_{50}H_{100}$  fits the  $C_nH_{2n}$  pattern, so it's either an alkene or a cycloalkane.

## Isomers

**Isomers:** Different structures (drawings) of substances with the same molecular formula.

- You can draw multiple isomers for a given molecular formula, like  $C_4H_8$ .
- When trying to name or draw isomers, it is important to consider the generic formulas.

## Isomers of $C_4H_8$

To systematically identify all isomers of  $C_4H_8$ , follow these steps:

1. Recognize the  **$C_nH_{2n}$  pattern**, indicating the presence of either **alkenes (double bonds)** or **cycloalkanes (rings)**.
2. Systematically draw all possible isomers of one type (e.g., alkenes) before moving on to the next (e.g., cycloalkanes).

## Alkenes (Eenes)

Start by drawing all possible alkenes with four carbons ( $C_4H_8$ ).

1. **But-1-ene**: A four-carbon chain with a double bond at the first carbon.
  - Structure:  $CH_2=CH-CH_2-CH_3$
2. **But-2-ene**: A four-carbon chain with a double bond in the middle (second carbon).
  - Structure:  $CH_3-CH=CH-CH_3$
3. **2-Methylprop-1-ene**: A three-carbon chain with a methyl group ( $CH_3$ ) attached to the middle carbon and a double bond at the first carbon.
  - Structure:  $CH_2=C(CH_3)-CH_3$

## Cycloalkanes (Rings)

Now, draw all possible cycloalkanes with four carbons ( $C_4H_8$ ).

1. **Cyclobutane**: A four-carbon ring.
  - Structure: A square where each corner is a carbon atom.
2. **Methylcyclopropane**: A three-carbon ring with a methyl group ( $CH_3$ ) attached to one of the carbons.
  - Structure: A triangle (cyclopropane) with a  $CH_3$  group attached to one of the corners. The position of the methyl group doesn't matter since it's the only substituent on the ring.

## Key Concepts

- **Isomers:** Molecules with the same molecular formula but different structural arrangements.
- **Systematic Approach:** A methodical way to approach isomer problems by dealing with one family (e.g., alkenes) and then the other (e.g., cycloalkanes).
- **Generic Formulas:** Useful for identifying the type of isomers to consider (e.g.,  $C_nH_{2n}$  suggests alkenes or cycloalkanes).

## Summary Table

Isomer Name	Structure Description
But-1-ene	Four carbons in a row, double bond at the first carbon
But-2-ene	Four carbons in a row, double bond in the middle
2-Methylprop-1-ene	Three carbons in a row, methyl group on the second carbon, double bond at the first carbon
Cyclobutane	Four-carbon ring
Methylcyclopropane	Three-carbon ring with a methyl group attached

In total, there are **five isomers** of  $C_4H_8$ .

# Isomers of Molecular Formulas

**Isomers** are distinct molecules sharing the same molecular formula but differing in structure and name. If two molecules appear different but have the same name, they represent the same molecule, merely rotated or flipped.

## Determining Isomer Types

Given the molecular formula  $C_6H_{10}$ , determine the possible types of isomers:

1. Establish the generic formula  $C_nH_{2n}$ . In this case, we have six carbons, so we double that to get twelve hydrogens.  $C_6H_{12}$  represents the number of hydrogens we would expect if the molecule was an alkane. We have less than that, so we subtract two to get  $C_6H_{10}$ . Thus, our pattern is  $C_nH_{2n-2}$ .
2. Consider possible structures based on the  $C_nH_{2n-2}$  pattern:
  - **Alkanes** ( $C_nH_{2n+2}$ ): Not possible.
  - **Alkenes** ( $C_nH_{2n}$ ): Not possible.
  - **Alkynes** ( $C_nH_{2n-2}$ ): Possible.
  - **Cycloalkanes** ( $C_nH_{2n}$ ): Not possible.
  - **Cycloalkenes** ( $C_nH_{2n-2}$ ): Possible.

Therefore, we can explore drawing **alkynes** and **cycloalkenes**.

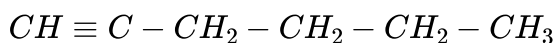
## Drawing Isomers Systematically

To systematically draw isomers, follow this approach:

1. Start with the longest chain and exhaust all possibilities.
2. Progress to the second-longest chain, and so on.

## Drawing Hexyne Isomers ( $C_6H_{10}$ )

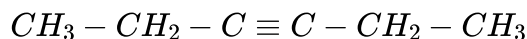
1. **Hex-1-yne:**



2. **Hex-2-yne:**



3. **Hex-3-yne:**



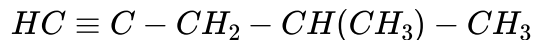
Moving the triple bond to the next position would result in a duplicate isomer (Hex-2-yne).

## Drawing Pentyne Isomers ( $C_5H_8$ ) with a Methyl Branch

1. **3-Methylpent-1-yne:**



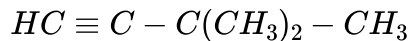
2. **4-Methylpent-1-yne:**



Moving the methyl group further would result in it becoming part of the longest chain.

## Drawing Butyne Isomers ( $C_4H_6$ ) with Two Methyl Branches

1. **3,3-Dimethylbut-1-yne:**



This is the only possible four-carbon-long isomer.

## 🔄 Drawing Cycloalkene Isomers

1. **Cyclohexene**: A six-membered ring with one double bond.
2. **Methylcyclopentene**: A five-membered ring with one double bond and a methyl substituent. When numbering, prioritize giving the double bond the lowest numbers, then the substituent.

## Additional Notes

- Systematically reducing the carbon chain length helps in identifying all possible isomers.
- Three-membered rings with triple bonds are generally not formed due to ring strain.
- As the size of the hydrocarbon increases, the number of possible isomers grows rapidly.

# Homologous Series

A **homologous series** is a sequence of organic compounds that share the same functional group and similar chemical properties, where each successive member differs by a  $\text{CH}_2$  group. Homologous series questions often appear in lab settings when choosing a manipulated variable in organic chemistry.

A bunch of molecules in the same family, where each consecutive member has an extra carbon. Adding an extra carbon requires an extra pair of hydrogens  *$\text{CH}_2$  unit*.

## Key Characteristics

- Same **functional group**: Each member of the series has the same functional group, dictating the chemical behavior.
- **Similar chemical properties**: Because of the same functional group, members exhibit similar reactions.
- **Gradual change in physical properties**: Physical properties like boiling point and melting point change gradually with increasing molecular size.
- **$\text{CH}_2$  difference**: Each member differs from the next by a  $\text{CH}_2$  unit.

## Application in Labs

Homologous series are valuable when studying the melting points of substances. Pick a homologous series to observe how the melting point changes with each additional  $\text{CH}_2$  unit.

## Naming and Drawing

1. **Identify the base molecule:** Start with a given molecule, like propene.
2. **Add a carbon:** Extend the carbon chain by one carbon atom.
3. **Add two hydrogens:** Add two hydrogen atoms for each additional carbon  $\text{CH}_2$ .
4. **Name the new molecule:** Update the name based on the new carbon count, following IUPAC nomenclature rules.
5. **Consider the position:** If necessary, add a number to denote the position of a functional group.

## Example 1: Propene Series

- **Propene:** Three carbons with a double bond at the first position.
- **But-1-ene:** Four carbons with a double bond at the first position.
- **Pent-1-ene:** Five carbons with a double bond at the first position.
- ...
- **Dec-1-ene:** Ten carbons with a double bond at the first position.

## Key Points

- The position of the double bond remains the same throughout the series.
- Only the parent chain length *stem* increases.
- Varying the position of the double bond, or the presence of the double bond, would exclude a molecule from the homologous series.

## Example 2: 2-Methyl Series

Consider a series based on a branched alkane with a methyl group, such as "2-methyl- with no number."

- **2-Methylpropane**: Three carbons in the main chain with a methyl group at the second position.
- **2-Methylbutane**: Four carbons in the main chain with a methyl group at the second position.
- **2-Methylpentane**: Five carbons in the main chain with a methyl group at the second position.
- ...
- **2-Methyloctane**: Eight carbons in the main chain with a methyl group at the second position.

## Key Points

- The methyl group's position remains constant throughout the series.
- The parent chain is the only thing growing.

## Controlled Variables

In an experiment using a homologous series, controlled variables are:

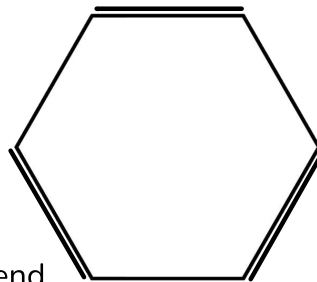
- Functional group *e. g. , doublebond, methylgroup*
- Position of substituents
- Only the parent chain *or stem* varies

# Aromatic Hydrocarbons

**Aromatic hydrocarbons** are a classification of hydrocarbons that contain one or more **benzene rings**.

## Benzene Ring

- A six-carbon ring structure.
- **Nonpolar**: No positive or negative end.
- Each carbon atom is bonded to one hydrogen atom.
- All bond lengths are the same.



Here's why they're called aromatic:

**Historical Reason:**

When chemists first discovered these compounds in the 19th century, many of them had distinctive pleasant smells (or aromas). Examples include:

- Benzene (almond-like smell)
- Toluene (sweet smell)
- Vanillin (vanilla scent)
- Cinnamaldehyde (cinnamon scent)

Because of this, they were named "aromatic compounds."

**Modern Chemical Definition:**

Today, aromaticity refers to a specific type of electron stability in ring-shaped molecules, not their smell.

To be aromatic, a compound must:

1. Be cyclic (form a ring)
2. Be planar (flat molecule)
3. Have a conjugated  $\pi$  electron system (alternating double and single bonds)
4. Follow Hückel's Rule: It must have  $4n + 2$   $\pi$  electrons (where  $n$  is a whole number)

Benzene is the classic example:

- It's cyclic and planar
- It has 6  $\pi$  electrons (which fits  $4n + 2$ , with  $n = 1$ ).
- It shows exceptional stability due to delocalized electrons in the ring.

**Key Point:**

They are called "aromatic" for historical reasons (because of their smell), but today the name refers to a molecule's electron structure and stability, not its odor.

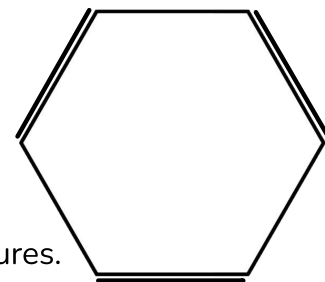
Everything that isn't an aromatic hydrocarbon is called **aliphatic**. This includes:

- Alkynes
- Alkenes
- Alkynes
- Cycloalkanes
- Cycloalkenes

Typo → what we mean is

- anes - cycloalkanes
- enes - cycloalkenes
- ynes

⇒ NO Benzene Ring!



## Structure of Benzene

The actual structure of benzene is an average of two resonance structures.

Here's how we determine the true nature of the bonds:

1. Draw both possible structures of benzene, alternating the double bonds.
2. Observe that there are three total bonds (a single and a double bond) between the two drawings.
3. Divide the total number of bonds by the number of structures ( $3 \text{ bonds} / 2 \text{ structures} = 1.5 \text{ bonds}$ ).

Thus, in reality, benzene has a bond and a half between each carbon atom. A typical exam question will ask, "How many double bonds are in benzene?". The answer is zero!

A bond and a half means that there are three electrons between each carbon, as each bond contains two electrons.

## Drawing Benzene

Since chemists don't have a way to draw a bond and a half, we have two acceptable ways to draw benzene:

1. A six-carbon ring with alternating single and double bonds.
2. A six-carbon ring with a circle inside.



The circle represents the delocalized electrons.

## What Isn't Benzene

A six-membered ring isn't necessarily benzene.

Structure	Name	Aromatic?
Six-membered ring with one double bond	Cycloalkene	No
Six-membered ring with two double bonds	Cyclodiene	No
Six-membered ring with three alternating double and single bonds	Benzene	Yes

## Naming Aromatic Compounds

### Benzene with One Alkyl Group

Name the alkyl group and add "benzene" to the end. Since the benzene ring has no beginning or end, the alkyl group is always in the one position, so we don't need to include the number.

**Example:** A benzene ring with a two-carbon branch is called ethylbenzene.

## Benzene Ring Branches

### Line Structure Strategy

When drawing branches off a **benzene ring**, remember:

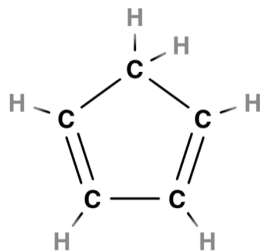
- diens  $\Rightarrow$  di: 2 ene: double bond  
 $\hookrightarrow$  any hydrocarbon w/ 2-double bonds

There are 3 types of dienes:

1. conjugated  $\rightarrow$  where double bonds are separated by one single bond.  $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$
2. cumulated  $\rightarrow$  where double bonds are back-to-back.  $\text{CH}_2=\text{C}=\text{CH}_2$
3. Isolated  $\rightarrow$  where double bonds are separated by two or more single bonds.  
 $\hookrightarrow \text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}=\text{CH}_2$

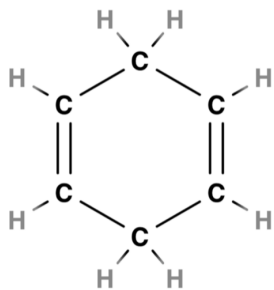
### Cyclo dienes

1. Conjugated



1,3-cyclopentadiene

2. isolated



1,4-cyclohexadiene

3. cumulated

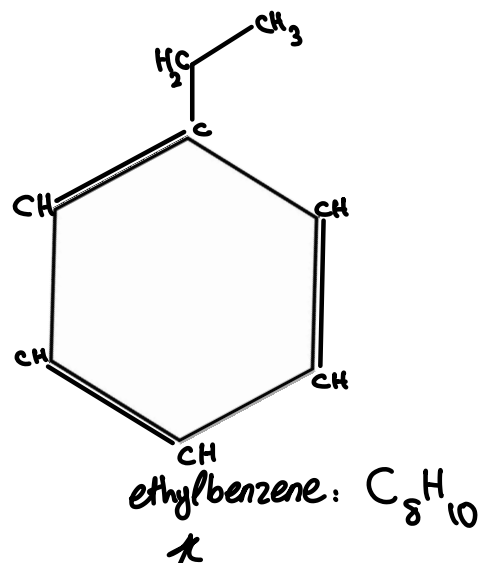
$\downarrow$   
rare in rings  
due to strain!

- When you drop your pen to draw a branch, it represents carbon zero.
- Circles can be added at every line meeting to help count carbons.
  - Example: Six carbons in the ring plus two for an ethyl branch equals eight carbons.
- Remove the circles after counting.

## Molecular Formula Calculation

Calculating the molecular formula involves:

1. Counting the number of carbon atoms.
2. Identifying the number of hydrogen atoms (H).
  - Visually check each carbon atom.
  - Remember, a branch eliminates one hydrogen.
  - A single line represents a bond and a half.



## Ethylbenzene Example

In ethylbenzene (benzene with one ethyl group):

- There are 6 carbons in the benzene ring and 2 in the ethyl group, totaling 8 carbons.
- Count the hydrogens: one on each carbon in the ring (except where the ethyl group attaches) and then the hydrogens in the ethyl group. This totals 10 hydrogens.
- The molecular formula is therefore  $C_8H_{10}$ .

## Benzene with Two Alkyl Groups

When benzene has two identical alkyl groups:

- Use "di-" to indicate two groups.
- Use numbers to specify the positions of the groups on the ring.
  - Numbering: Determine the shortest route between the two groups.
- Remember, a single line in the ring represents one and a half bonds, so there are only four possible bonds for each carbon.

## Positional Arrangements

- 1,2-: The groups are neighbors.
- 1,3-: One carbon separates the groups.
- 1,4-: The groups are as far apart as possible.
  - These are the only three possible number combinations for "di-" substituted benzenes.

## Two Different Alkyl Groups

With two different alkyl groups attached to a benzene ring:

- Order the numbering alphabetically.
- The alkyl group that comes first alphabetically gets the "1" position.
- Minimize the numbering for the other group.
  - If there are three things, you'd pick the first alphabetical and set the numbers from there.

## Example: Ethyl and Methyl

In a molecule with both ethyl and methyl groups, ethyl gets the "1" position because "e" comes before "m."

## Aromatic vs. Aliphatic

**Aromatic hydrocarbons** contain a benzene ring. **Aliphatic hydrocarbons** do not.

## Benzene as a Branch

benzene

When a benzene ring is a branch off a long carbon chain, it's called **phenyl**, not benzene. This is because the benzene ring is treated as an alkyl group in this case.

## Nomenclature Convention

Use "-yl" ending, like alkyl branches, even though **phenyl** isn't an alkyl branch.

## Decoding Complex Structures

To tackle complex organic structures:

1. Identify the **parent chain or stem**.
2. Identify the **end** (e.g., double bond).
3. Work through branches step by step.

- One carbon: **Meth** (e.g., methyl)
- Two carbons: **Eth** (e.g., ethyl)
- Three carbons: **Prop** (e.g., propane, propyl)
- Four carbons: **But** (e.g., butane, butyl)
- Five carbons: **Pent** (pentagon)
- Six carbons: **Hex** (hexagon)
- Seven carbons: **Hept**
- Eight carbons: **Oct** (octagon)
- Nine carbons: **Non**
- Ten carbons: **Dec**

- Metaphor: *"How do you eat an elephant? One bite at a time."*

## Example: Deciphering 2-methyl-3,3-diphenylpent-1-ene

1. **Stem**: Pent (five carbons). Draw five carbons in a row.
  2. **End**: -1-ene (double bond at the first carbon). Add a double bond between the first and second carbons.
  3. **Branches**:
    - 2-methyl: A methyl group (one carbon) on the second carbon.
    - 3,3-diphenyl: Two phenyl groups (benzene rings as branches) on the third carbon.
  4. Complete the structure by adding hydrogens to satisfy the bonding capacity of each carbon (four bonds total).
- ## Aromatic Groupings
- If a structure has at least one **benzene ring**, it is called **aromatic**.
  - If a structure has no benzene rings, it is called **aliphatic**.

# Organic Halides

Organic halides, also known as hydrocarbon derivatives, involve replacing at least one hydrogen atom with a halogen. There could be two or three halogens, and you don't even need any hydrogen at all.

## Naming Conventions

- Number from an end to give the lowest number to the **substituents**.
- If there's a tie, go alphabetic.
- Use prefixes like "di-" for two halogens, "tetra-" for four halogens, etc.

## Halogens

Halogens are named as follows:

- Fluoro
- Chloro
- Bromo
- Iodo

## Example: 2,2-Dichlorobutane

1. Identify the **stem**: Butane (four carbons).
2. Locate the **substituents**: Two chlorine atoms at position 2.

### PART 2: Five Noncyclic Isomers of $C_6H_{14}$ (Hexane)

All have the formula  $C_6H_{14}$  (alkanes):

1. **n-Hexane**:  $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$
2. **2-Methylpentane**:  $CH_3-CH(CH_3)-CH_2-CH_2-CH_3$
3. **3-Methylpentane**:  $CH_3-CH_2-CH(CH_3)-CH_2-CH_3$
4. **3,3-Dimethylbutane**:  $CH_3-C(CH_3)_2-CH_2-CH_3$
5. **2,3-Dimethylbutane**:  $CH_3-CH(CH_3)-CH(CH_3)-CH_3$

## Structural Representations

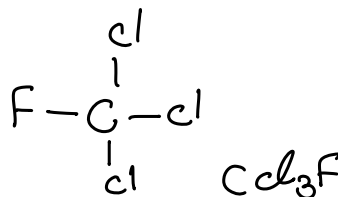
### Line Structures

- Carbons and hydrogens are typically not explicitly written.
- Atoms other than carbon and hydrogen must be explicitly written.
- The end of a line segment, if not labeled, represents a carbon atom. If an atomic symbol is present, then that is the only atom present at the end of that segment.

## Condensed Structures

Write out the molecule with **all the atoms present**.

### Example: Trichlorofluoromethane <sup>C</sup>

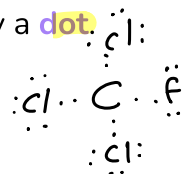


- **Stem:** Methane (one carbon).
- **Substituents:** Three chlorines and one fluorine.
- Formula:  $CCl_3F$
- Carbon comes before hydrogen, so chlorine is listed first, then fluorine.

## Line Structure for Methane

Since methane has only one carbon atom, the line structure is represented by a **dot**.

### Representing Trichlorofluoromethane in a Line Structure



Add the chlorine and fluorine atoms to the dot representing methane:

- Three chlorine atoms (Cl)
- One fluorine atom (F)

# Alcohols: Hydrocarbon Derivatives

Alcohols are **hydrocarbon derivatives** because they contain elements other than just carbon (C) and hydrogen (H).

**Functional Group: Hydroxyl**  $\rightarrow -OH \Rightarrow$  what makes alcohols alcohol.

The unique **functional group** that defines alcohols is the **hydroxyl group** (-OH).

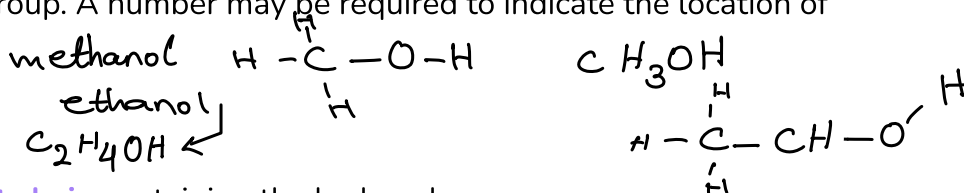
A **functional group** is a specific group of atoms within a molecule that is responsible for the characteristic chemical reactions of that molecule.

It is important to note that the hydroxyl group in alcohols is **covalently bonded** to a carbon atom and is different from **hydroxide** (OH<sup>-</sup>), which is an ion found in ionic compounds. Calcium hydroxide is an ionic compound, not an alcohol.

## Naming Alcohols

Naming alcohols is based on the **alkane stem**. The "-ol" ending indicates the presence of a hydroxyl group. A number may be required to indicate the location of the hydroxyl group.

Here's the process:



1. Identify the **longest chain** containing the hydroxyl group.
2. Drop the last "-e" from the alkane name.
3. Add "-ol" to the stem.
4. Use a number to indicate the position of the hydroxyl group, if necessary.

For example, a three-carbon chain with a hydroxyl group on the first carbon would be named **propan-1-ol**.

## Drawing Alcohols

Structural diagrams of alcohols include a dash from the carbon to an oxygen, then a dash from the oxygen to a hydrogen (C-O-H).

For line structures:

1. Draw the carbon chain.
2. Add a line segment with an "O" at the end to represent the hydroxyl group.
3. Write in the "H" of the hydroxyl group because it doesn't connect to carbons.

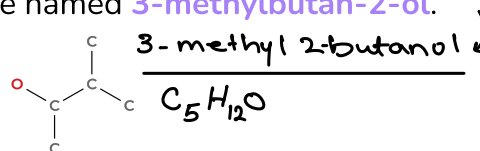
When drawing line structures, circling the ends of line segments helps to visualize the structure, especially at the carbon atoms.

## Complex Examples

When dealing with more complex molecules containing both a hydroxyl group and branches, follow these steps:

1. Identify the **longest chain** containing the hydroxyl group.
2. Number the chain to give the hydroxyl group the lowest possible number.
3. Name the alcohol, including the position of the hydroxyl group.
4. Name and number any branches.

For example, a four-carbon chain with a hydroxyl group on the second carbon and a methyl group on the third carbon would be named **3-methylbutan-2-ol**.

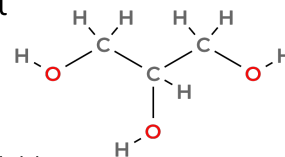


## Multiple Hydroxyl Groups

Alcohols can have more than one hydroxyl group. When naming alcohols with multiple hydroxyl groups, the same rules apply, except the "-e" in the alkane name is **not** dropped.

Use prefixes like "-di-", "-tri-", and "-tetra-" to indicate the number of hydroxyl groups. More than one number will be needed to denote the position of each hydroxyl group.

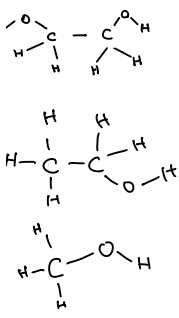
For example, a three-carbon chain with a hydroxyl group on each carbon would be named **propane-1,2,3-triol**.



It is important to realize the potential for isomers. In propane-1,2,3-triol, all three hydroxyl groups do not necessarily have to be on different carbons.

## Everyday Alcohols

Connecting the concepts learned in the course to everyday compounds is important.



Alcohol	Carbons	Hydroxyl Groups	Use
Ethane-1,2-diol $C_2H_6O_2$ Ethylene Glycol	2	2	<b>Antifreeze.</b> It is highly soluble in water and is commonly mixed in a 50/50 ratio with water in car engines.
Ethanol $C_2H_5O$	2	1	<b>Alcoholic beverages.</b> It is toxic, but can be consumed in low quantities.
Methanol $CH_4O$	1	1	Highly toxic alcohol that can cause blindness and death if ingested.

## Methanol vs. Ethanol in Winemaking

During winemaking and distilling, it's crucial to remove **methanol** ( $CH_3OH$ ).

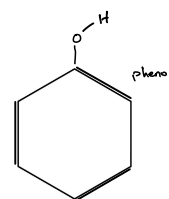
Methanol boils off before ethanol, and it must be discarded due to its toxicity. **Ethanol** ( $C_2H_5OH$ ) is the desired product that can be kept.

## Phenols

**Phenol** is a common structure in chemistry, similar to benzene, and has its own name due to its importance. It's an alcohol derived from an aromatic ring.

Phenol consists of a phenyl group (an aromatic ring) bonded to a hydroxyl group (-OH). It can undergo reactions typical of alcohols.

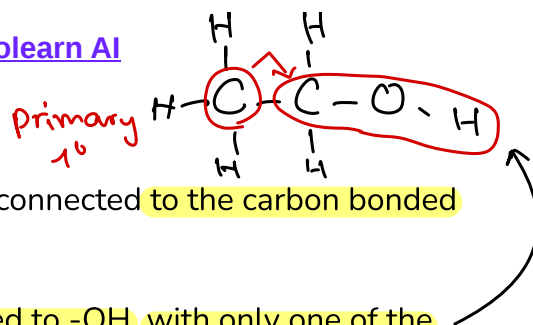
It is generally not for human consumption.



## Primary, Secondary, and Tertiary Alcohols

The position of the **hydroxyl group** (-OH) significantly affects the type of reactions an alcohol can undergo. In organic chemistry, it is important to identify primary, secondary, and tertiary alcohols.

## Primary Alcohols ( $1^\circ$ )



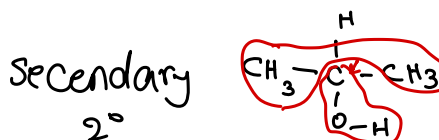
In **primary alcohols**, there is **one carbon** connected to the carbon bonded to the hydroxyl group (C-OH).

Visually, the structure includes a carbon bonded to -OH, with only one of the remaining three bonds connected to another carbon. The other two bonds are connected to hydrogen atoms. Primary alcohols often have the hydroxyl group at the end of the carbon chain, indicated by "-1-ol" in the name. They are very reactive and undergo specific types of reactions.

Example:  $R - CH_2 - OH$

Where R can be any carbon chain.

## Secondary Alcohols (2°)



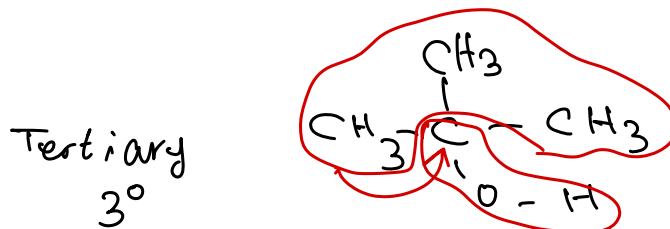
In **secondary alcohols**, there are two carbons connected to the carbon bonded to the hydroxyl group (C-OH).

The structure features a carbon bonded to -OH, with two of the remaining three bonds connected to carbon atoms, and the third bond connected to a hydrogen atom. The presence of two carbon attachments to the central carbon determines its secondary classification.

Example:  $R_1 - CH(OH) - R_2$

Where  $R_1$  and  $R_2$  can be any carbon chains.

## Tertiary Alcohols (3°)



In **tertiary alcohols**, there are three carbons connected to the carbon bonded to the hydroxyl group (C-OH).

The structure consists of a carbon bonded to -OH, with all three remaining bonds connected to carbon chains. There is no hydrogen atom directly connected to the carbon bearing the hydroxyl group. Tertiary alcohols are less reactive due to the hydroxyl group being "protected" or "blocked" by the surrounding carbon chains, leading to different reaction mechanisms.

Example:  $R_1R_2R_3C - OH$

Where  $R_1$ ,  $R_2$ , and  $R_3$  can be any carbon chains.

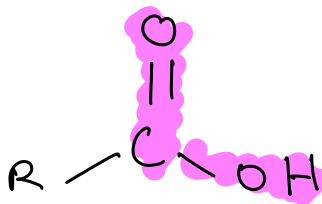
## Summary Table

Alcohol Type	Description	General Formula	Reactivity
Primary	One carbon connected to the carbon bonded to -OH	$R - CH_2 - OH$	High
Secondary	Two carbons connected to the carbon bonded to -OH	$R_1 - CH(OH) - R_2$	Moderate
Tertiary	Three carbons connected to the carbon bonded to -OH	$R_1R_2R_3C - OH$	Low

## Alcohol Family Review

- **Hydroxyl Group:** -OH (not hydroxide)
- **Nomenclature:** Alcohols can have one or more hydroxyl groups.
- **Classification:** Alcohols can be classified as primary, secondary, or tertiary based on the number of carbon atoms attached to the carbon atom bearing the hydroxyl group.

# Carboxylic Acids



**Carboxylic acids** are a family of organic compounds characterized by the presence of a **carboxyl functional group**.

A **carboxyl group** consists of a carbon atom **double-bonded to an oxygen atom ( $C = O$ )** and **single-bonded to a hydroxyl group ( $OH$ )**.

It's crucial to distinguish between an **alcohol** and a **carboxylic acid** when you see an  $OH$  group. The presence of a double-bonded oxygen ( $C = O$ ) next to the hydroxyl group indicates a carboxyl group, not an alcohol.

## Carboxyl Group Structure

A carboxyl group comprises two key components:

- **Hydroxyl group ( $OH$ )**
- **Carbonyl group ( $C = O$ )**: A carbon double-bonded to an oxygen

The hydrogen atom in the  $OH$  portion of the carboxyl group is acidic and can be removed.

## Naming Carboxylic Acids

The naming rules for carboxylic acids are similar to those for other organic compounds.

1. Drop the "e" from the alkane stem name.
2. Add "oic acid."
  - Example: Propane becomes propanoic acid.

Let's look at a three-carbon example:

1. Identify the parent chain: In this case, it is three carbons long, so we start with "propane."
2. Drop the "e": "propan-"
3. Add "oic acid": **Propanoic acid**

## Numbering

Do we need to include a number in the name to indicate the position of the **carboxyl group**? Could the carboxyl group be located in the middle carbon? Let's investigate.

If we were to place the carboxyl group on the middle carbon, the carbon atom with the carboxyl group would have five bonds, which is impossible.

Therefore, the carboxyl group must always be at the end of the carbon chain. Thus, we never need to include a number in the name to indicate the position of the carboxyl group. The carboxyl group is always located at carbon number one.

## Benzoic Acid

**Benzoic acid** is an **organic compound** with a benzene ring and a carboxyl group attached to it.

To attach the carboxyl group, you can't put it directly on the benzene ring because there's not enough bonding capacity. You must go up to another carbon that has enough bonding capacity to have a double-bonded *O* and an *OH*.

Benzoic acid is commonly used in ester labs and as a building block for pharmaceuticals.

## Naming Practice with Substituents

When naming carboxylic acids with substituents, follow this sequence:

1. Identify the **parent chain** or stem.
2. Add the **"oic acid"** ending.
3. Address any **alkyl groups** or **halogens** that have been added.

Consider the example of 3-chloropropanoic acid:

1. "Prop-" indicates a three-carbon chain.
2. "Oic acid" indicates the presence of a carboxyl group ( $C = OOH$ ) attached to one end of the chain. Because it is on the end, we know to begin numbering from that carbon.
3. "3-chloro" indicates that a chlorine atom is attached to the third carbon atom in the chain.

## Line Structure Representation

To draw the line structure for 3-chloropropanoic acid:

1. Draw three carbon atoms in a zig-zag line to represent the parent chain.
2. Add a double bond to one end carbon to represent the carbonyl group ( $C = O$ ).
3. Add a line to the same carbon to represent the  $OH$  group. The hydrogen on the  $OH$  must be shown explicitly because it is not connected to a carbon atom.
4. Add a line to the third carbon atom to represent the chlorine atom ( $Cl$ ).

# Predicting Boiling Points and Solubility

The goal of this lesson is to predict the boiling points of different organic compounds and to make solubility predictions. Fractional distillation is a key topic.

## Intermolecular Forces

To predict boiling points and solubilities, we need to understand the three intermolecular forces:

1. London Dispersion Forces
2. Dipole-Dipole Forces
3. Hydrogen Bonding

## London Dispersion Forces

- Present in every molecule.
- Caused by the random motion of electrons.
- Electrons are attracted to the nucleus of another atom, causing attraction between molecules.

The more electrons a molecule has, the stronger the London dispersion forces.

**Example:** Methane ( $\text{CH}_4$ ) vs. Ethane ( $\text{C}_2\text{H}_6$ )

Ethane ( $\text{C}_2\text{H}_6$ ) has more carbons and hydrogens, thus more electrons than methane ( $\text{CH}_4$ ). Therefore, ethane has stronger London dispersion forces. The bigger the hydrocarbon, the higher its boiling point.

## Dipole-Dipole Forces

- Caused by permanent polarity, resulting in permanent positive and negative ends.
- Less emphasized in this unit for breaking ties.

**Example:** Fluoromethane

Fluorine is highly electronegative (4.0) compared to carbon (2.6). This difference creates a dipole moment, with fluorine being slightly negative and carbon slightly positive.

- Fluoromethane has both London dispersion forces and dipole-dipole forces.

## Hydrogen Bonding

- An extreme dipole interaction.
- Occurs when hydrogen is bonded to oxygen (O), nitrogen (N), or fluorine (F).
- Mnemonic: Hydrogen only wants to have "f-o-n."
  - In organic chemistry, we focus on O-H bonds in alcohols and carboxylic acids.

### Examples:

- **Methanol (alcohol):** Contains London dispersion forces, is polar, and has an O-H bond for hydrogen bonding.
- **Methanoic acid (carboxylic acid):** Has London dispersion forces, is polar, and exhibits hydrogen bonding due to the O-H bond.

## Ranking Boiling Points

Lowest boiling point corresponds to the fewest forces, while the highest boiling point requires the most energy to separate molecules, indicating the strongest forces.

### Example 1: Ranking Hydrocarbons

Rank the following from lowest to highest boiling point:

- Hexane ( $C_6H_{14}$ )
- Methane ( $CH_4$ )
- Butyne ( $C_4H_6$ )

All molecules have London dispersion forces. Hydrocarbons (C's and H's only) are nonpolar and do not have dipole-dipole forces or hydrogen bonding. The ranking depends on the number of electrons (size):

1. Methane ( $\text{CH}_4$ ) - Least electrons, lowest boiling point
2. Butyne ( $\text{C}_4\text{H}_6$ ) - Second most electrons
3. Hexane ( $\text{C}_6\text{H}_{14}$ ) - Most electrons, highest boiling point

### Example 2: Methanol vs. Methanediol

Compare methanol and methanediol to determine which has the greater boiling point.

- Methanol:  $\text{CH}_3\text{OH}$
- Methanediol:  $\text{CH}_2(\text{OH})_2$

Analysis of Forces:

Force	Methanol ( $\text{CH}_3\text{OH}$ )	Methanediol ( $\text{CH}_2(\text{OH})_2$ )
London Dispersion	Present	Greater (extra O)
Dipole-Dipole	Present	Present
Hydrogen Bonding	One O-H group	Two O-H groups

Since both molecules have London dispersion forces, dipole-dipole forces, and hydrogen bonding, we focus on the differences in London dispersion and hydrogen bonding.

- Methanediol has more electrons (more significant London dispersion forces) and two O-H groups (more substantial hydrogen bonding).
- Therefore, methanediol has a greater boiling point than methanol.

## Forces by Family Summary

Family	Molecular Composition	Polarity	Intermolecular Forces
Hydrocarbons	C and H only	Nonpolar	London dispersion forces only

When comparing hydrocarbons, ranking is primarily based on size and electron count. If isomers have the same molecular formula, branching can be considered to break the tie.

## Boiling Points of Isomers

The more **branched** a hydrocarbon isomer is, the **lower** its boiling point. This is because branching affects how closely molecules can pack together, influencing intermolecular forces.

- **Straight-chain isomers:** Can align closely, maximizing London dispersion forces (LDF).
- **Branched isomers:** Have a greater distance between molecules, reducing the effectiveness of LDF.

**Example:** Isomers of  $C_4H_{10}$

- **Butane (straight chain):** Higher boiling point due to closer alignment and stronger LDF.
- **Methylpropane (branched):** Lower boiling point because the branch spaces the molecules further apart, weakening LDF.

To visualize this, consider several  $C_4H_{10}$  molecules:

- **Butane (straight chain):** Molecules can align closely.

```
1 2 3 4
1 2 3 4
1 2 3 4
```

- **Methylpropane (branched):** Branches create distance between molecules.

```
  2
  |
1-3-4

  2
  |
1-3-4
```

## Organic Halides

Organic halides can exhibit either LDF only or both LDF and dipole-dipole forces, depending on their structure.

- **LDF Only:** Occurs when the halide is symmetric around the carbon, causing bond polarities to cancel out.
  - **Example:** Tetrafluoromethane ( $CF_4$ ) - Four polar C-F bonds cancel each other out.
- **LDF and Dipole-Dipole Forces:** Occurs when there is an uneven distribution of halogens around the carbon, resulting in a net dipole moment.
  - **Example:** A chloromethane molecule ( $CH_3Cl$ ) - The polar C-Cl bond is not canceled out by the C-H bonds.

Keep in mind that molecules are three-dimensional with bond angles of approximately 109.5 degrees, even if they are drawn flat on paper.

## Alcohols

Alcohols exhibit all three types of intermolecular forces:

- London Dispersion Forces (LDF)
- Dipole-Dipole Forces
- Hydrogen Bonding

This is due to the presence of a **hydroxyl group (-OH)**.

- **Example:** Ethanol ( $CH_3CH_2OH$ ) contains a very polar bond between the oxygen and hydrogen atoms in the hydroxyl group that causes hydrogen bonding.

## Carboxylic Acids

Carboxylic acids also exhibit all three types of intermolecular forces:

- London Dispersion Forces (LDF)
- Dipole-Dipole Forces
- Hydrogen Bonding

This is due to the presence of both a carbonyl group ( $C=O$ ) and a hydroxyl group (-OH).

- **Example:** Methanoic acid (formic acid,  $HCOOH$ ) contains an extreme dipole-dipole interaction (hydrogen bonding) due to the hydroxyl group (-OH) as well as LDF.

## Comparing Intermolecular Forces

When comparing compounds with similar electron counts, the strength of intermolecular forces typically follows this order:

1. Carboxylic acids (highest due to hydrogen bonding and dipole-dipole)
2. Alcohols (hydrogen bonding)
3. Polar organic halides (dipole-dipole and LDF)
4. Hydrocarbons (LDF only)

If multiple molecules have hydrogen bonding, such as ethanol, methanol, and propanol, London dispersion forces become the deciding factor.

## Practice Examples

To determine which species has a higher boiling point or melting point, identify the intermolecular forces present and their relative strengths.

1. Hexane vs. Butane
2. Methane vs. Water
3. 1-Bromopropane vs. 1-Chloropropane
4. Nonane vs. 3-Ethylheptane

# Solubility: "Like Dissolves Like"

The principle of "like dissolves like" suggests that **solubility** is highest when the solute and solvent have similar intermolecular forces. There are two main scenarios for high solubility:

## Nonpolar Substances

- When both the solute and solvent are **nonpolar**, meaning they exhibit only **London dispersion forces LDF**.
- These are often referred to as **hydrophobic** substances, as they have low solubility in water.

### Example:

- A mixture of heptane  $C_7H_{16}$  and octane  $C_8H_{18}$ .
- This combination is highly soluble due to both compounds having LDF only.

Gasoline, which you buy at stations like Petro Canada or Esso, is a common example. It's a mixture of hydrocarbons, primarily around C7 to C10. Higher octane fuels contain a more uniform solution of octane with fewer other hydrocarbons.

## Hydrogen Bonding Substances

- When both the solute and solvent can form **hydrogen bonds**.

### Example:

- Ethanol  $C_2H_5OH$  in water  $H_2O$ .
- Ethanol is incredibly soluble in water due to both substances' capacity for hydrogen bonding.

## Concentrations

- Alcoholic beverages contain varying percentages of ethanol in water *e. g.* , 5.
- Vodka can have high ethanol concentrations *e. g.* , 80.
- E85 fuel is a mixture of 85% ethanol and 15% gasoline, used in vehicles designed to run on it.
  - Pure ethanol is dangerous and can be lethal if consumed in large quantities.

## Solubility Chart

Type of Intermolecular Force	Solubility
Nonpolar <i>LDF only</i>	High
Hydrogen Bonding	High
Dipole-Dipole	Medium/Low

Substances with dipole-dipole forces will generally have medium to low solubility and will not be highly soluble in either nonpolar or hydrogen-bonding solvents.

## Fractional Distillation: Separating Hydrocarbons

**Fractional distillation** is a crucial process in the oil industry for separating hydrocarbons from crude oil.

Crude oil is a complex mixture that needs to be separated into various products for different applications, such as gasoline for cars and diesel for trucks.

## Process

1. Crude oil enters a **fractional distillation tower**.
2. The oil is heated, causing the hydrocarbons to vaporize.
3. The tower has a temperature gradient: cooler at the top and hotter at the bottom.
4. As the vapor rises, different hydrocarbons condense back into liquids at different heights, depending on their boiling points.
5. Liquids are collected at various levels in the tower.

## Hydrocarbon Separation

- **Hydrocarbons** are separated based on their **boiling points**, which are directly related to their size and the strength of their **London dispersion forces**.
- Larger hydrocarbons *more electrons* have higher boiling points.
- Smaller hydrocarbons *fewer electrons* have lower boiling points.

## Tower Gradient

- **Top of the Tower:**
  - Lowest boiling points.
  - Smaller hydrocarbons *e. g.* , *C1 to C3*.
- **Middle of the Tower:**
  - Intermediate boiling points.
  - Medium-sized hydrocarbons *e. g.* , *C5 to C9*, like those used in gasoline.
- **Bottom of the Tower:**
  - Highest boiling points.
  - Largest hydrocarbons and materials that don't boil, such as tars and asphalt, which are used for roads and shingles.

## Fractional Distillation Chart

Tower Level	Boiling Point	Hydrocarbon Size	Example Product
Top	Lowest	Small <i>C1 – C3</i>	Gases
Middle	Intermediate	Medium <i>C5 – C9</i>	Gasoline
Bottom	Highest	Large <i>C20+</i>	Tars, Asphalt

## Important Considerations

- The key concept to remember is the order of hydrocarbons as they are separated in the tower:
  - Lowest boiling points at the top.
  - Highest boiling points at the bottom.
- Fractional distillation towers are very large, often several stories tall.

# Reaction Types

When studying for exams and quizzes, connect the **family** of molecules to the **type of reaction** they undergo.

## Addition Reactions

- Occur only with **enes** and **ynes** (alkenes and alkynes).
- Require a second or third bond (a pi bond).

*Definition:*

A **sigma bond** is the first bond between two atoms.

A **pi bond** is the second or third bond between two atoms. Pi bonds break more easily than sigma bonds.

- Double and triple bonds between carbons (pi bonds) can be broken to add something in.
- Example: Adding hydrogen ( $H_2$ ) to propene ( $C_3H_6$ ):
  - Propene ( $C_3H_6$ ) + Hydrogen ( $H_2$ ) → Propane ( $C_3H_8$ )
  - The pi bond in propene breaks, and a hydrogen atom adds to each carbon of the original double bond.
- Example: Adding hydrogen ( $H_2$ ) to propyne ( $C_3H_4$ ):
  - Propyne ( $C_3H_4$ ) + Hydrogen ( $H_2$ ) → Propene ( $C_3H_6$ )
  - Only one mole of hydrogen is added for every one mole of propyne, breaking one of the extra bonds.
- Example: Propyne ( $C_3H_4$ ) with excess hydrogen ( $H_2$ ):
  - Propyne ( $C_3H_4$ ) + 2 Hydrogen ( $2H_2$ ) → Propane ( $C_3H_8$ )
  - Enough hydrogen is added to break all pi bonds (the triple and the double bonds).
  - **Unsaturated** reactants become **saturated** products.
- Example: Adding chlorine ( $Cl_2$ ) to propene ( $C_3H_6$ ):
  - Propene ( $C_3H_6$ ) + Chlorine ( $Cl_2$ ) → 1,2-dichloropropane ( $C_3H_6Cl_2$ )
  - The extra bond breaks, and chlorine adds to each side of the original double bond.
  - The family changes from an **ene** to an **organic halide**.
  - The intermolecular forces change from **LDF only** to **LDF and dipole-dipole forces**.

## Substitution Reactions

- Occur only with **anes** (alkanes).
- Involve breaking single (sigma) bonds.
- Require high energy, such as ultraviolet (UV) radiation, to break the sigma bond.

## Elimination Reactions

- The opposite of addition.
- Involve organic halides or alcohols making **enes** (alkenes).
- Involve taking something away to create a double bond.
- Alcohols can also undergo elimination reactions to make **enes** (alkenes).

## Esterification Reactions

- Alcohols plus carboxylic acids produce esters.
- The only reaction where two organic compounds react.
- Esters have unique smells; for example, some esters mimic the smell of strawberries or bananas.

*Metaphor:*

Strawberry-flavored bubble gum doesn't contain real strawberries; it contains an ester that mimics the smell of strawberries.

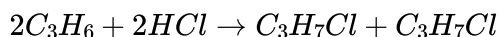
## Reaction Types Summary

Starting Material	Reaction Type	Product
Enes/Ynes	Addition	Change in family
Anes	Substitution	Change in family
Organic Halides	Elimination	Enes
Alcohols	Elimination	Enes
Alcohol + Carboxylic Acid	Esterification	Ester

## Addition Reactions in Detail

### Addition of Hydrogen Halides

- Example: Adding hydrogen chloride ( $HCl$ ) to propene ( $C_3H_6$ ):
  - Propene ( $C_3H_6$ ) + Hydrogen Chloride ( $HCl$ )  $\rightarrow$  1-chloropropane ( $C_3H_7Cl$ ) + 2-chloropropane ( $C_3H_7Cl$ )
  - The pi bond breaks, and the hydrogen and chlorine atoms add to the carbons of the original double bond.
  - Two possible products: 1-chloropropane and 2-chloropropane.
  - In high school chemistry, both possibilities must be considered, and the equation must be balanced. In organic chemistry, you learn to discern between major and minor products.
  - Balanced equation: 2 Propene + 2 Hydrogen Chloride  $\rightarrow$  1-chloropropane + 2-chloropropane



- Ensure that you don't draw two products that have the same name; they are not two products, they are one.

## Addition Reactions with Water

Let's explore addition reactions by adding water ( $H_2O$ ) to alkenes. Remember, when we see a double or triple bond, we know it can break and open up spots for new atoms or groups to bond.

### Propane Example

When water is added to **propene**, you can think of water as  $H - OH$ . The  $H$  adds to one side of the broken double bond, and the  $OH$  adds to the other. This can result in two different products:

- **Propane-1-ol**: The  $OH$  group adds to the end carbon.
- **Propane-2-ol**: The  $OH$  group adds to the middle carbon.

These products are **isomers**, meaning they have the same molecular formula ( $C_3H_8O$ ) but different structures and properties. The change in properties is significant:

- **Alkene**: London Dispersion Forces (LDF) only
- **Alcohol**: LDF, dipole-dipole interactions, and hydrogen bonding

Alkenes are versatile starting materials in engineering, as they can be converted into many different types of compounds.

## Ethene Example

Let's consider a simpler case: adding water to **ethene**. We break the double bond, creating two open spots. Thinking of water as  $H - OH$ , we add an  $H$  to one carbon and an  $OH$  to the other.

In this case, whether the  $OH$  adds to the "left" or "right" carbon, the result is the same: **ethanol** ( $CH_3CH_2OH$ ). There's only one possible product here due to the symmetry of ethene.

## Balancing Equations

Make sure to balance equations. For example, in the propane example, the correct balanced equation is:



**Important Note:** Be careful when there are one or two carbons. In these cases, you probably won't get two products due to symmetry.

## Substitution Reactions with UV Light

Now, let's switch gears to **substitution reactions**. Here, we'll replace hydrogen atoms with other atoms or groups.

## Pentane and Bromine Example

Consider the reaction of **pentane** with **bromine** ( $Br_2$ ). Since pentane has only single bonds, we need ultraviolet (UV) radiation to initiate the reaction. UV light breaks the sigma bonds, allowing substitution to occur.

**Substitution Reaction:** A reaction in which one atom or group of atoms is replaced by another atom or group of atoms.

If you mix pentane and bromine in a test tube and expose it to sunlight, the reaction will occur. This is why chemicals that you don't want to react are often stored in brown bottles to block UV light.

## Reaction Steps

1. **Initiation:** UV light causes the diatomic bromine ( $Br_2$ ) to split into two bromine radicals ( $Br\cdot$ ).
2. **Propagation:** A bromine radical abstracts a hydrogen atom from pentane, forming  $HBr$  and a pentyl radical. The pentyl radical then reacts with another  $Br_2$  molecule, forming a bromopentane and another bromine radical, which can continue the chain reaction.
3. **Termination:** Two radicals combine to form a stable molecule, such as  $Br\cdot + Br\cdot \rightarrow Br_2$ .

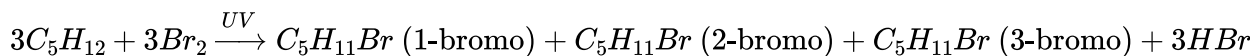
## Multiple Products

Unlike addition reactions, substitution reactions can yield multiple products. Let's analyze the possible products for the pentane and bromine reaction:

1. **1-bromopentane:** This occurs when a bromine atom substitutes a hydrogen atom on one of the end carbons.
2. **2-bromopentane:** This occurs when a bromine atom substitutes a hydrogen atom on a carbon one away from the end.
3. **3-bromopentane:** This occurs when a bromine atom substitutes a hydrogen atom on the middle carbon.

## Balancing the Equation

To balance the equation, we need three pentane molecules and three bromine molecules for the three possible substitution reactions:



## Key Differences from Addition

- **Addition:** Usually results in one or two products, depending on what is being added.
- **Substitution:** Can result in many products, depending on the size and structure of the hydrocarbon.

## Diploma Exam Tip

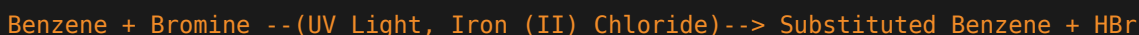
Be mindful of whether UV light is present in substitution reactions. If a reaction occurs with chlorine (or bromine) and there is no UV light, then the starting material must be an alkene or alkyne (unsaturated hydrocarbon).

Condition	Result
Chlorine + UV	Substitution reaction occurs.
Chlorine + No UV	No reaction with alkanes. Reaction <i>only</i> occurs with alkenes/alkynes.

Let's delve into substitution reactions with an aromatic example, emphasizing what we need to know about **benzene**.

I'm going to represent benzene using a line structure with double bonds rather than a circle.

Consider benzene reacting with bromine:



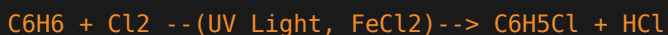
Now, how many double bonds are in benzene? It might visually appear to have three, but the correct answer is **none**. Despite its appearance, benzene doesn't undergo addition reactions because it doesn't have double bonds in the way that you might expect.

Since we're in the substitution section, benzene **can** undergo substitution, but it requires **UV light** and often another **catalyst**, such as **Iron (II) chloride**.

## Process

1. Any one of the hydrogen atoms (H) on the benzene ring can be substituted.
2. It doesn't matter which corner of the benzene ring the substitution occurs at; the substitution will always be in the one position, as there's only one thing connected to the ring.
3. One of the chlorine atoms will add to the ring, plucking off an H.
4. The second chlorine atom will pair up with the H.

The Iron (II) chloride acts as a **catalyst**, so it doesn't appear in the final products.



If there were already substituents on the ring, multiple products could form, with the new substituent adding one, two, or three positions away. But with nothing on the ring to start, we only get one product.

## Summary of Reaction Types

We've covered the first two reaction types. Let's build a summary that we'll continue to add to.

Your questions might involve an **alkene** or **alkyne** undergoing a reaction.

Alkenes and alkynes undergo **addition** reactions.

Organic chemistry often works well with flashcards. Consider making one flashcard per reaction type to memorize the parameters, inputs, and outputs.

Reaction Type	Reactant	Product	Conditions
Substitution	Benzene + Cl	Substituted Benzene + HCl	UV light, FeCl <sub>2</sub>
Addition	Alkene or Alkyne		

# Addition Reactions Review

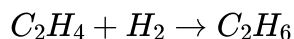
This review covers addition reactions from the Alberta Chem 30 organic chemistry unit perspective.

## Adding Hydrogen Gas to an Ene

In **addition reactions**, only the second or third bond in an organic compound is broken.

Consider adding hydrogen gas ( $H_2$ ) to ethene ( $C_2H_4$ ). The second bond in ethene breaks, and one hydrogen atom is added to each side of the double bond.

The product will be two carbons with the four original carbon-hydrogen bonds, plus the two added hydrogen atoms. When the double bond breaks, each carbon gains one extra bonding capacity, and a hydrogen atom can then be added to each side. So, an **ene** turns into an **ane**.



Since hydrogen gas is symmetric from right to left, it does not matter which hydrogen is added to which side; the same product is obtained.

## Adding HCl to Ethene and Propene

When adding a molecule that is not symmetric from right to left, you have to consider the potential products that could be formed.

Consider adding HCl to ethene:

- The hydrogen (H) could add to either the left-hand carbon or the right-hand carbon, potentially giving two different products.
- However, in this case, adding the H to either side results in the same molecule: chloroethane.

If you switch the H and Cl around, you still have chloroethane, so you only need to show the molecule once.

**Important:** Do not draw the same molecule twice if it is, in fact, the same molecule just rotated or flipped.

## Adding HCl to Propene

When adding HCl to propene, two different molecules with two different names are obtained. Therefore, both molecules must be drawn.

1. **First product:** Add the H from HCl to the left-hand side and the chlorine to the middle carbon, resulting in 2-chloropropane.
2. **Second product:** Add the chlorine to the terminal carbon and the hydrogen to the middle carbon, resulting in 1-chloropropane.

So, the two possible products are 2-chloropropane and 1-chloropropane.

You also need to balance the chemical reactions. For the chem 30 level, you only need to list the two potential products. In college or university-level chemistry, you will learn which one is more favored (the major product) and which one is the minor. Here, we are listing all possibilities.



You will need two of the propenes in order to make both of those products. You're going to need two HCl molecules in order to make those two products.

**Addition Reaction** An addition reaction is a chemical reaction where atoms are added to an unsaturated organic compound (typically containing double or triple bonds), resulting in a saturated compound or a compound with fewer multiple bonds.