Organic Chemistry Test Prep

This study guide is designed to help you prepare for your organic chemistry unit test or diploma exam. Keep in mind that while some content may refer to diploma exams, the information is equally applicable to unit tests. Expect around 12 out of 60 questions on the diploma exam to be focused on organic chemistry.

General Outcomes

There are two general outcomes in every unit of chemistry:

1. Exploring organic chemistry as a common form of matter.
2. Reaction-focused outcomes.

The first general outcome focuses on **drawing, writing, and interpreting** the **functional groups** present in organic compounds.

General Intro to Organic Molecules

An **organic molecule** must contain **carbon**. However, some carbon-containing molecules are considered inorganic. Here are a few examples to watch out for:

Carbons that are inorganic

- **Carbonates**: Compounds containing the CO_3^{2-} ion. These will often appear with a positive ion, such as sodium carbonate (Na_2CO_3).
- **Cyanides**: Compounds containing the CN^- ion, such as sodium cyanide.
- **Carbides**: Carbon combined with metals (less common on exams).
- **Oxides of Carbon**: Carbon dioxide (CO_2) and carbon monoxide (CO) are not considered organic.

Example Question

Which of the following are organic?

Use the following information to answer numerical-response question 1.

Eight Chemical Compounds

1 $CO_2(g)$	5 $Co(OH)_2(s)$
2 $CH_3OH(l)$	6 $NaCN(s)$
3 $H_2CO_3(aq)$	7 $CH_3COOCH_3(aq)$
4 $ClCH_3(l)$	8 $HCOOH(l)$

2 4 7 8

1. CO_2
2. CH_3CH_2OH
3. H_2CO_3
4. CH_3Cl
5. Co
6. $NaCN$
7. CH_3COOCH_3
8. $COOH$

Answer:

- Not organic: CO_2, H_2CO_3, Co, $NaCN$
- Organic: CH_3CH_2OH, CH_3Cl, CH_3COOCH_3, $COOH$

Connections to Everyday Life

This outcome ($C1.2$) focuses on the connection between organic molecules and everyday life. Familiarize yourself with the following examples:

- **Oil Industry/Fossil Fuels**:
  - Methane, propane (natural gases)
  - Octane (gasoline)
  - Diesel fuel (longer carbon chains)
- **Vinegar**: Ethanoic acid (used in cooking)
- **Benzene**: A solvent
- **Polymers**: Polyethene
- **Glucose**: A sugar
- **Ethanol**: An alcohol that adults over 18 can consume
- **Ethane with two alcohols (a diol)**: Antifreeze

Drawing Structures Using IUPAC Rules

This outcome (1.3) requires you to draw structures using IUPAC rules for the following:

- Alkanes, alkenes, alkynes
- Cycloalkanes and cycloalkenes
- Aromatic compounds (with a benzene ring)
- Organic halides
- Alcohols
- Carboxylic acids and Esters

Alkanes

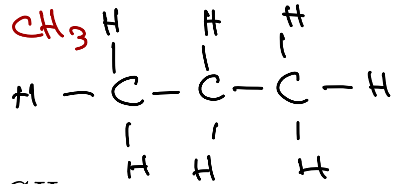
Alkanes are hydrocarbons containing only single bonds.

A simple alkane example is propane (C_3H_8). The "ane" ending indicates single bonds between carbons. Alkanes follow the general formula:

3 single bonds

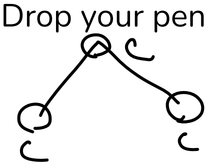
C_nH_{2n+2}

CH3–CH2–CH3



For propane (C_3H_8):

- Structural Formula: $CH_3CH_2CH_3$
- Condensed Formula: $CH_3CH_2CH_3$
- Line Structure: Drop your pen three times to make a line with two bends.

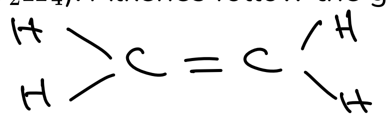


Alkenes

Alkenes are hydrocarbons containing at least one double bond.

Example: Ethene (C_2H_4). Alkenes follow the general formula:

C_nH_{2n}



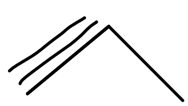
- Line Structure: Draw two lines between the carbons to represent the double bond.

Alkynes

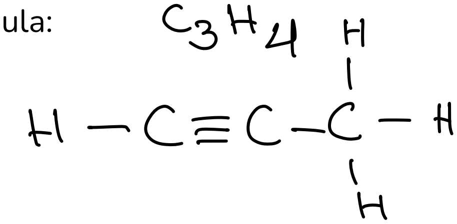
Alkynes are hydrocarbons containing at least one triple bond.

Alkynes follow the general formula:

C_nH_{2n-2}



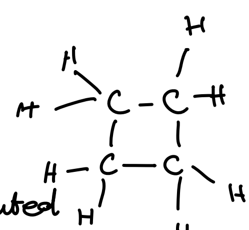
C3H4



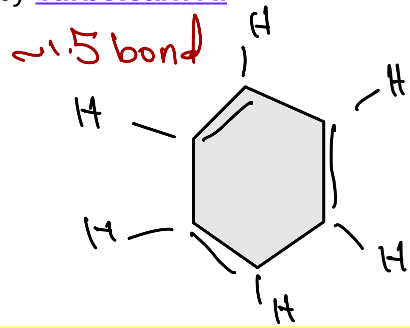
Cycloalkanes

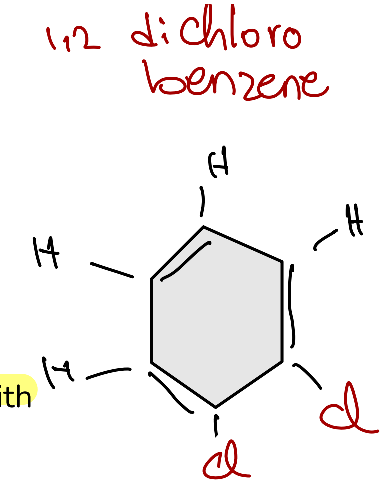
Cycloalkanes are alkanes that form a ring structure.

CnH2n saturated



These are named by adding "cyclo" to the beginning of the alkane name. For example, cyclobutane (four carbons in a ring) has the formula C_4H_8.





- Line structure: A square

Aromatic Compounds

> Aromatic compounds contain a benzene ring (a six-carbon ring with delocalized electrons).

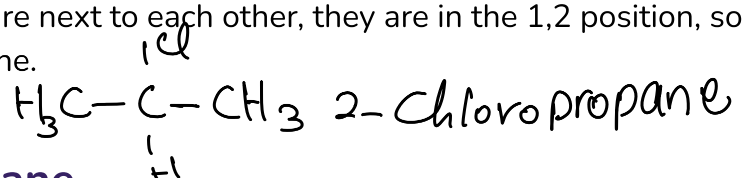
Benzene is often drawn with alternating double and single bonds, but in reality, the bonds are all equivalent with a bond order of 1.5.

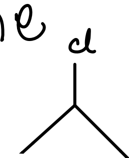
Naming Organic Halides

When naming organic halides, the position of the halogen (chlorine, fluorine, bromine, or iodine) is indicated by a number.

- The carbon chain is numbered to give the halogen the lowest possible number.
- If there is only one halogen, the number can be omitted.
- If there are multiple halogens, prefixes like *di-* (2), *tri-* (3), and *tetra-* (4) are used.
- If there are different halogens, they are listed alphabetically (e.g., bromochloro).

For example, if we have a benzene ring (C_6H_6) with two chlorines (Cl) attached to it, it's a dichloro. If the chlorines are next to each other, they are in the 1,2 position, so the name is 1,2-dichlorobenzene.





Example: Chloropropane

Consider a three-carbon alkane (propane) with a chlorine atom attached:

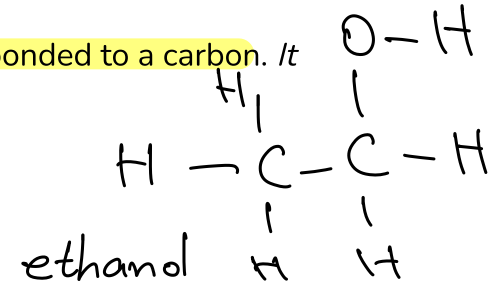
- If the chlorine is on one of the end carbons, it's in the 1 position.
- If the chlorine is in the middle carbon, it's in the 2 position, and the name is 2-chloropropane.

In line structure, propane is represented as three line segments. To indicate the chlorine atom, write "Cl" at the end of the line segment connected to the middle carbon.

Alcohols

Alcohols have an -OH group (hydroxyl group) attached to a carbon chain.

> A hydroxyl group is an -OH group covalently bonded to a carbon. *It should not be confused with the hydroxide ion.*



To name an alcohol:

1. Identify the parent alkane.
2. Replace the -e with -ol.
3. Add a number between the n and ol to indicate the position of the -OH group.
   - However, if the -OH group can only be at one position, the number is not needed.

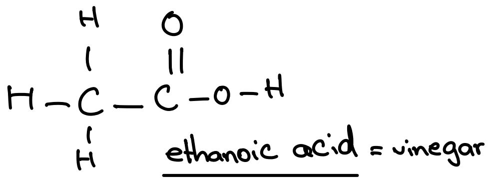
For example, a two-carbon alcohol (CH_3CH_2OH) is ethanol. The -OH group is at the end position, so it is technically ethane-1-ol, but the "1" is dropped because it's implied.

Carboxylic Acids

Carboxylic acids have a carboxyl group (-COOH) at the end of a carbon chain.

> A carboxyl group is a combination of a carbonyl group ($C = O$) and a hydroxyl group (-OH) attached to the same carbon.

Because the carboxyl group must be at the end of the carbon chain, no number is needed to indicate its position.



To name a carboxylic acid:

1. Identify the parent alkane.
2. Replace the -e with -oic acid.

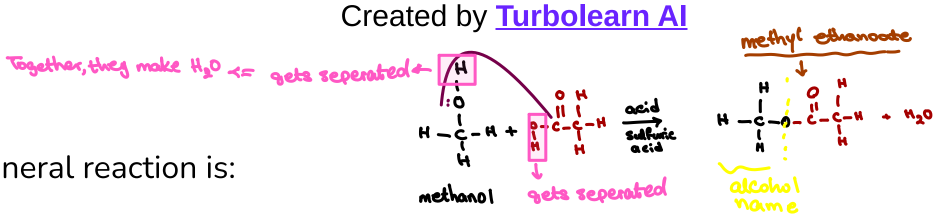
For example, a two-carbon carboxylic acid (CH_3COOH) is ethanoic acid, commonly known as vinegar.

Esters

Esters are formed from the reaction of an alcohol and a carboxylic acid.

> Esterification is the reaction between an alcohol and a carboxylic acid, typically requiring an acid catalyst (e.g., sulfuric acid).

The general reaction is:



$$Alcohol + CarboxylicAcid \xrightarrow{AcidCatalyst} Ester + Water$$

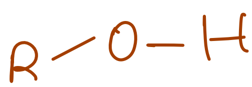
Naming an ester involves identifying the alcohol and carboxylic acid components. The alcohol part is named first as an alkyl group, and the carboxylic acid part is named as an alkanoate.

For example, methanol (CH_3OH) reacts with ethanoic acid (CH_3COOH) to form methyl ethanoate (CH_3COOCH_3).

Identifying Functional Groups

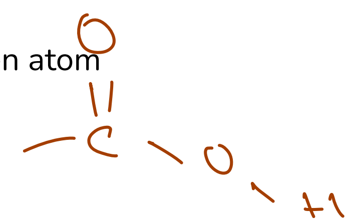
Hydroxyl Group

The hydroxyl group is a $O - H$ covalently bonded to a carbon or carbon chain (often represented as R-OH).



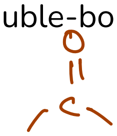
Carboxyl Group

The carboxyl group is a carbon atom with a double bond to an oxygen atom (carbonyl) and a single bond to a hydroxyl group ($COOH$).



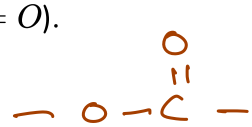
Carbonyl Group

The carbonyl group ($C = O$) is simply a carbon double-bonded to an oxygen, which may or may not be part of a carboxyl group.



Ester Linkage

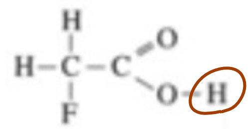
An ester linkage has an oxygen atom connected to a carbon atom, which is double-bonded to another oxygen atom ($O - C = O$).



Halides

Sodium fluoroethanoate, $NaCH_2FCOO(aq)$, is a potent metabolic poison that can be used to kill rodents. The conjugate acid of the fluoroethanoate ion is fluoroethanoic acid, $CH_2FCOOH(aq)$.

Fluoroethanoic Acid



if it was carbon → it would be Ester!

should be a branch : no branch.

Structure

I	Methyl
II	Carboxyl ✓
III	Ester linkage
IV	Halogen ✓

methyl: C – C

4. The structure(s) numbered above found in fluoroethanoic acid is/are

A. I and II

B. II only

C. II and IV

D. III and IV

Halides are fluorine, chlorine, bromine, or iodine atoms (F, Cl, Br, I) attached to a carbon chain.

Example Problem

Consider a molecule with multiple functional groups. To identify them:

- Look for branches, carboxyl groups, ester linkages, and halogens.
- Methyl groups are branches.
- Carboxyl groups have $COOH$.
- Ester linkages have $O - C = O$ with carbons on both sides of the molecule.
- Halogens are F, Cl, Br, I.

Structural Isomers

Structural isomers have the same molecular formula but different structural arrangements. Generic formulas help identify possible isomers:

Compound Type	Generic Formula
Alkane	C_nH_{2n+2}
Alkene	C_nH_{2n}
Alkyne	C_nH_{2n-2}
Cycloalkane	C_nH_{2n}
Cycloalkene	C_nH_{2n-2}

For example, to draw all isomers of C_4H_{10}:

1. Determine the type of compound. In this case, it's an alkane (C_nH_{2n+2}).
2. Start with the longest chain and work down.

The first isomer is a straight chain of four carbons (butane).

Isomers

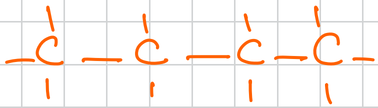
For the C10H22 example, two isomers can be formed:

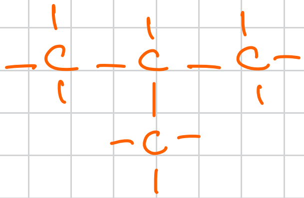
- **Butane**: a straight chain of 10 carbons.
- **Methylnonane**: a nine-carbon chain with a methyl group (CH3) branch on the second carbon.

C_4H_{10} : isomers

C_nH_{2n+2} : single bonds

- -ane: C_nH_{2n+2} → single bond
- -ene: C_nH_{2n} → one double bond
- -yne: C_nH_{2n-2} → one triple bond
- cycloane: C_nH_{2n}
- cycloene: C_nH_{2n-2}

(1)  butane

(2)  methyl propane

- for making isomers, the carbon will change on the longest chain

Homologous series: chains of -anes, -enes, ... ⇒ we have to refer to the forces in chem 20:

- LDF — an organic hydrocarbon only has LDF, no D-D, no hydrogen bonds.
- Hydrogen bonds
- D-D

There are only two isomers in this case. On diplomas, you will likely be asked how many isomers there are, so you need to perfect this skill.

Boiling Points Within a Homologous Series

Within a **homologous series**, you're looking at a series of alkanes, alkenes, or alkynes.

> A **homologous series** is a sequence of organic compounds with the same functional group and similar chemical properties in which the series can be branched or unbranched.

Consider ranking these straight-chain alkanes from highest to lowest boiling point: propane, ethane, and pentane.

Remember your Chem20 forces. For hydrocarbons (compounds with only C and H), you only need to consider **London dispersion forces**. Hydrocarbons do not have dipole-dipole or hydrogen bonding forces.

The more electrons a molecule has, the larger it is and the stronger its London dispersion forces will be. Therefore:

- Pentane (5 carbons) has the highest boiling point. most LDF → heighest boiling point (→ more carbon)
- Propane (3 carbons) has the second-highest boiling point.
- Ethane (2 carbons) has the lowest boiling point.

Even if the members are not consecutive, the principle still applies.

You should also be able to rank molecules with different functional groups. For example, rank propanoic acid, propene, and propanol from lowest to highest boiling point.

- **Propanoic acid** (an acid) can hydrogen bond due to the OH group, and it also has a polar carbonyl group (C=O).
- **Propanol** (an alcohol) has an OH group and can hydrogen bond.
- **Propene** only has London dispersion forces.

Therefore, the ranking is:

1. Propene (lowest boiling point)
2. Propanol
3. Propanoic acid (highest boiling point)

Questions will generally fall into these two categories: homologous series or compounds with different functional groups. Remember your intermolecular forces from Chem20.

Fractional Distillation and Solvent Extraction

Fractional distillation has appeared on almost every diploma exam.

> Fractional distillation is the separation of a mixture into its component parts, or fractions, separating chemical compounds by their boiling point by heating them to a temperature at which one or more fractions of the compound will vaporize.

In fractional distillation, heat is applied at the bottom, and there is cooling as you go up the column. Only the lowest boiling points will make it to the top.

- The smallest hydrocarbons with the lowest boiling points make it to the top.
- The largest hydrocarbons with the largest London dispersion forces come out the bottom.
- Very large hydrocarbons like tars and asphalt may not even boil and will simply melt and come out the bottom.

If you are given a list of hydrocarbons, apply your knowledge of boiling point properties.

Solvent extraction is less common but is appearing more often.

> Solvent extraction is a method to separate compounds based on their relative solubilities in two different, immiscible liquids, usually water and an organic solvent.

You need to use your knowledge of intermolecular forces and solubility. For example, if you want to extract butane (C4H10) from the ground, you need to realize that butane is a hydrocarbon with only London dispersion forces. Therefore, you need a solvent that is also a hydrocarbon with London dispersion forces to dissolve and extract the butane. Water would not work because it has hydrogen bonding and would repel the butane.

When choosing a solvent, look for high solubility.

Reaction Types

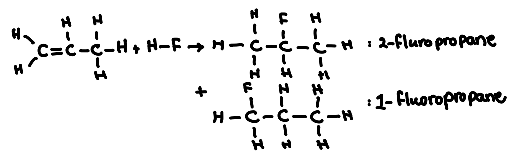
General outcome two focuses on these reaction types:

- Addition
- Substitution
- Elimination (can be broken into two types)
- Esterification (already discussed)
- Combustion (complete and incomplete)

Addition Reactions

Addition reactions require a double or triple bond. The first bond between two atoms is a strong sigma bond, while the second bond is a weaker pi bond.

When the pi bond breaks, bonding capacity is freed up on both sides, allowing you to add something to it.



For example, consider the addition of HF to propene:

$$CH_3CH = CH_2 + HF \rightarrow CH_3CHFCH_3 + CH_3CH_2CH_2F$$

When the double bond breaks, the H and F can add in two possible ways, resulting in two different products:

- 2-fluoropropane
- 1-fluoropropane

These are isomers of each other. There can be one or two answers to all addition problems, but sometimes the products are the same due to symmetry.

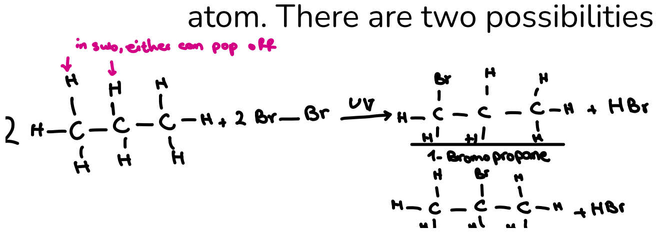
Substitution Reactions

In substitution reactions, you typically substitute a hydrogen atom with UV light.

For example, consider the reaction of propane with bromine in the presence of UV light:

$$C_3H_8 + Br_2 \xrightarrow{UV light} CH_3CH_2CH_2Br + CH_3CHBrCH_3 + HBr$$

With ultraviolet radiation, one of the hydrogen atoms can be replaced by a bromine atom. There are two possibilities:



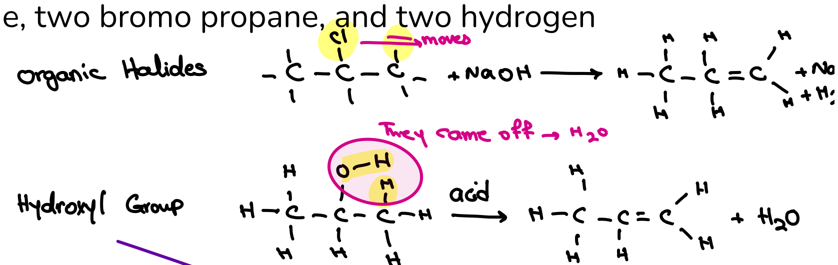
- The bromine can replace a hydrogen at the end, resulting in 1-bromopropane.
- The bromine can replace a hydrogen in the middle, resulting in 2-bromopropane.

In both cases, HBr is also produced as an inorganic product.

Reactions of Organic Compounds

Substitution Reactions

- The most common substitution reaction involves **organic compounds**.
- The mechanism involves UV light creating radicals with bromine, resulting in a **bromide**.
- Example:
    - Reactants: Two organic compounds and two bromine molecules.
    - Products: One bromo propane, two bromo propane, and two hydrogen bromides.



Elimination Reactions

Dehydrohalogenation

- Involves the **elimination of a halogen** (e.g., chlorine) and a hydrogen from an organic halide.
- Requires **sodium hydroxide** ($NaOH$) to remove the hydrogen and create a double bond.
- Chlorine acts as a **leaving group**, and a neighboring hydrogen is also removed.
- Example: Two chloropropane + $NaOH$ -> propene + sodium chloride + water

Dehydration

- Involves the **removal of water** from an alcohol using an acid catalyst.
- Requires an **acid catalyst** that is bulky and does not add to the reaction.
- Example: Alcohol + Acid Catalyst -> Alkene + Water
- In both types of elimination reactions, consider the potential for **multiple products** if removing hydrogen from either side results in different compounds.

Combustion

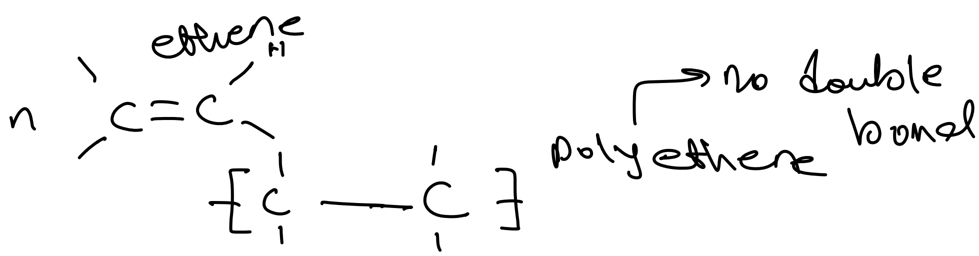
Complete Combustion

- Involves a fuel reacting with oxygen to produce **carbon dioxide** and **water vapor**.
    - $CH_4 + O_2 -> CO_2 + H_2O$
- This is a basic concept from science.

Incomplete Combustion

- Occurs when there is a **limited amount of oxygen**.
- Products include:
    - **Carbon dioxide** (CO_2): A greenhouse gas.
    - **Carbon monoxide** (CO): A toxic, odorless gas.
    - **Soot**: An air pollutant.
    - **Water vapor** (H_2O).

Polymerization



Addition Polymers

- Involves monomers with a **double bond** (e.g., ethene).
- The **second bond** is broken, and monomers add to form a long chain.

  A **monomer** is a small molecule that can bond to other identical molecules to form a polymer.

A polymer is a large molecule composed of repeating structural units (monomers).

- The repeating pattern is written in brackets with a dash, indicating continuous addition.
- The name of the polymer is "poly-" followed by the monomer name (e.g., polyethene).
- Example: polyethylene : industry name
    - Monomer: Ethene
    - Polymer: Polyethene : IUPAC
- The polymer does not have a double bond.
- Commonly used in plastics.

Condensation Polymers

- Involves two different monomers: an alcohol and an acid.
- Requires two functional groups (two OH groups in the alcohol and two carboxyl groups in the carboxylic acid).
- Monomers add in an alternating pattern (alcohol-acid-alcohol-acid).
- Example: Polyester (alcohol piece + acid piece repeating).

Natural Polymers

- Carbohydrates:
    - Monomers: Monosaccharides
    - Disaccharides
    - Polymer: Carbohydrates
- Proteins:
    - Monomers: Amino acids
    - Polymers: DNA or RNA

Thermal Energy Production

- Organic compounds, especially fossil fuels, are burned to produce thermal energy (heat).
- Examples include:
  - Natural gases (C_1 to C_3)
  - Butane (C_4), liquid at standard ambient temperature and pressure (SATP)
  - Fuels (C_{12} to C_{14}): Jet fuel, gasoline, diesel fuel.

Trends in Student Performance

- Students often struggle with:
  - Solvent extraction
  - Fractional distillation
  - Polymer section## Working Backwards from Polymers to Monomers

It's usually easier to predict the polymer given the monomer, but sometimes you'll have to work backwards. For example, given a polymer with two chlorines, you might be asked to identify the monomer.

To solve this:

1. Recognize the number of carbons in the monomer.
2. Maintain the position of functional groups like chlorines (Cl) on different carbons.
3. Introduce a double bond to transition from the polymer structure to the monomer if it's an **addition polymer**.

Hydrocarbons and Derivatives

- **Hydrocarbons**: Compounds containing only carbon (C) and hydrogen (H).
- **Hydrocarbon Derivatives**: Hydrocarbons with additional elements like oxygen (O) or halogens (X).

Halogens are sometimes represented as "X" in chemical formulas.

⌬ Benzene Representation

Benzene can be represented in two ways:

- With alternating single and double bonds.
- With a circle inside the hexagon to represent delocalized electrons.

Make sure you're familiar with both notations for tests and diplomas.

Alcohols vs. Phenols

- **Alcohol**: A hydroxyl group (OH) attached to an aliphatic (non-aromatic) carbon.
- **Phenol**: A hydroxyl group (OH) attached to a benzene ring.

насыщение Saturated vs. Unsaturated

When determining saturation, focus **only** on carbon-carbon bonds. Do not consider double bonds within functional groups.

- **Saturated**: All carbon-carbon bonds are single bonds, and the carbon is "full" of hydrogen.
- **Unsaturated**: Contains at least one carbon-carbon double or triple bond.

The Bromine Test

The bromine test is used to determine saturation.

> Diatomic bromine (Br_2) reacts with **unsaturated** compounds (alkenes and alkynes) via **addition**, causing a color change.

- **Positive Test (Unsaturated)**: Bromine color changes from brown/orange to clear.
- **Negative Test (Saturated)**: No immediate color change.

Bromine can react with alkanes (saturated) over a long period **only** in the presence of UV light via **substitution**.

Functional Groups

You might be asked to identify functional groups in compounds, even if you can't name the entire molecule. For example, acetylsalicylic acid (aspirin) contains a carboxy group and an ester linkage.

ароматический Aromatic vs. Aliphatic

- **Aromatic Compounds**: Contain a benzene ring.
- **Aliphatic Compounds**: Do not contain a benzene ring.

Solubility

Solubility of organic compounds can be generalized into two categories:

1. Substances with **London dispersion forces only** are highly soluble in each other (e.g., hexane and heptane).
2. Substances capable of **hydrogen bonding** are highly soluble in each other, often involving water.

Organic halides are generally **not** highly soluble in water due to the lack of hydrogen bonding.

Color Changes in Reactions

Color changes indicate a reaction has occurred. You can analyze:

- Color change in the organic compound itself.
- Color change of the added reagent (e.g., bromine or potassium permanganate).

Hydrocarbon Cracking

Hydrocarbon cracking involves breaking a large alkane into smaller molecules, including at least one alkene. For example:

$$C_{20}H_{42} \rightarrow C_{10}H_{22} + C_{10}H_{20}$$

This is classified as an **elimination reaction**.

Substitution Reactions

The most common substitution reaction involves an alkane reacting with a halogen in the presence of UV light:

$$Alkane + Halogen \xrightarrow{UV Light} Halogenated Alkane + HX$$

Polymerization

Study both **addition** and **condensation** polymerization, including:

- Identifying monomers and polymers.
- Working backwards from polymer structures to monomers.

Organic Chemistry Basics

Organic chemistry is the study of **carbon-containing compounds**. This definition is historical and distinct from "organic" food labeling. The unit is worth 20% of the diploma exam weighting.

Hydrocarbons vs. Hydrocarbon Derivatives

- **Hydrocarbons**: Compounds containing only carbon (C) and hydrogen (H).
  - Example: Methane (CH_4)
- **Hydrocarbon Derivatives**: Compounds containing carbon and hydrogen, plus at least one other element.
  - Examples: Alcohols, carboxylic acids, and halides (containing Group 7A/17 elements like chlorine, fluorine, bromine, or iodine).

Non-Organic Carbon Compounds

Certain carbon-containing compounds are *not* classified as organic. These include:

- Ionic derivatives of carbon
  - Carbonates (CO_3^{2-})
  - Cyanides (CN^-)
  - Carbides (metals + carbon)
- Oxides of carbon
  - Carbon dioxide (CO_2)
  - Carbon monoxide (CO)

You may encounter these in assessments such as:

- Sodium carbonate (Na_2CO_3)
- Hydrogen cyanide (HCN)
- Potassium cyanide (KCN)
- Tungsten carbide (WC)

Bonding Review (Chem 20 Recap)

Organic compounds feature **molecular bonding** via the sharing of electrons. There is no ionic bonding in organic compounds.

Bonding Capacity by Group

The number of bonds an atom typically forms can be determined by its Lewis structure. Here's a review for key elements:

Element	Group	Valence Electrons	Single Electrons	Bonds
Carbon	4A	4	4	4
Nitrogen	5A	5	3	3
Oxygen	6A	6	2	2
Halogens	7A	7	1	1
Hydrogen	1A	1	1	1

Drawing Organic Molecules

1. Carbon must always have **four** bonds.
2. Hydrogen must always have **one** bond and is always on the outside of the molecule.
3. Line up carbons in a row.
4. Use bonding capacity to figure out where to put double or triple bonds.

Structural Diagrams

Structural diagrams show how atoms are connected in a molecule.

Methane (CH_4)

Carbon needs four bonds, and hydrogen needs one. Therefore, carbon goes in the middle, attached to four hydrogen atoms.

```
    H
    |
H - C - H
    |
    H
```

Propane (C_3H_8)

Line up the three carbons. Add hydrogen to the carbons until they each have four bonds.

```
    H   H   H
    |   |   |
H - C - C - C - H
    |   |   |
    H   H   H
```

Ethene (C_2H_4)

Putting the two carbons together, you'll find that a double bond is needed to satisfy the bonding requirements of carbon.

```
    H   H
    |   |
C = C
    |   |
    H   H
```

Naming Conventions (Chem 20)

The prefixes for the first 10 carbon counts **must be memorized**.

> If an organic molecule has one carbon in its longest chain, you're going to see "meth-" in its name.

If there are branches coming off of a hydrocarbon chain, the carbon count for the branch is indicated similarly, but with a "-yl" ending. For example, a one-carbon branch is a "methyl" group.

Nomenclature of Organic Molecules

Prefixes for Carbon Chains

When naming organic molecules, prefixes indicate the number of carbons in the chain or branch:

- 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**

Note: Prefixes for five- to ten-carbon chains are similar to those used in mathematics and science but lack the "a" (e.g., nonane vs. nona-).

Identifying the Stem and Branches

- **Stem:** The longest continuous chain of carbon atoms in a molecule.
- **Branch:** A side group attached to the stem.

To name a molecule:

1. Identify the longest carbon chain (stem).
2. Identify and name any side branches.
3. Determine the type of bonds (single, double, or triple).

Naming Conventions

- The stem name includes a prefix indicating the number of carbons.
- Side branches are named using the prefix for the number of carbons, followed by "-yl" (e.g., methyl).
- Endings indicate the type of bonds:
  - **ane**: single bonds
  - **ene**: double bonds
  - **yne**: triple bonds

Alkanes: A Family of Organic Compounds

Alkanes are organic compounds containing only carbon and hydrogen atoms connected by single bonds.

> Alkanes are **hydrocarbons** with only single bonds between carbon atoms.

Naming Alkanes

1. **Identify the longest carbon chain.**
2. **Name the stem** using the appropriate prefix and the "-ane" ending.
3. **Identify any branches** and name them using the appropriate prefix and the "-yl" ending.
4. **Number the carbon atoms** in the longest chain to give the branch the lowest possible number.
5. **Write the name** as: (branch number)-(branch name)(stem name).

Example: Naming a seven-carbon alkane (Heptane):

1. Identify the longest chain: Seven carbons.
2. Name the stem: Heptane.
3. If there is a one-carbon branch (methyl) on the second carbon, the name is 2-methylheptane.

Types of Structures

- **Structural Diagrams:** Show all atoms and bonds.
- **Condensed Structures:** Represent the sequence of atoms without showing all bonds.
  - Example: The condensed structure of heptane is $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$.

Locating and Naming Branched Alkanes

When naming branched alkanes, identify the longest continuous carbon chain, even if it's not a straight line. If there are multiple paths with the same number of carbons, choose one as the stem.

IUPAC Nomenclature

The International Union of Pure and Applied Chemistry (IUPAC) establishes naming rules to provide precise instructions for drawing a structure from its name.

- **Numbering:** Count from the end of the longest chain that gives the lowest number to the first branch.

Dealing with Multiple Branches

When a molecule has multiple branches, each branch must be identified and numbered according to its position on the longest carbon chain.

Prefixes for Multiple Alkyl Groups

When naming organic molecules, we often encounter situations where there are multiple identical alkyl groups attached to the main carbon chain. To simplify the naming process, we use prefixes to indicate the number of these groups.

- **di-**: Indicates two identical groups.
- **tri-**: Indicates three identical groups.
- **tetra-**: Indicates four identical groups.

When using these prefixes, it is crucial to specify the location of each group with numbers separated by commas. For example, if you use "di-", you must provide two numbers indicating the positions of the two groups.

Example: 2,2-dimethylpentane indicates a pentane molecule with two methyl groups attached to the second carbon.

Rules for Naming Alkanes, Alkenes, and Alkynes

Here's a breakdown of the rules for naming alkanes, alkenes, and alkynes:

1. Find the Longest Chain:
    - Identify the longest continuous chain of carbon atoms.
    - Use the stem name corresponding to the number of carbons in this chain (e.g., meth-, eth-, prop-, but-, pent-, hex-, hept-, oct-).
2. Add a Suffix:
    - For alkanes (single bonds), use the suffix "-ane".
    - For alkenes (double bonds), use the suffix "-ene".
    - For alkynes (triple bonds), use the suffix "-yne".
3. Numbering for Alkenes and Alkynes:
    - Alkanes do not require a number because single bonds are assumed to be everywhere.
    - For alkenes and alkynes, indicate the position of the double or triple bond by numbering the carbon-carbon bonds.

Example of Naming an Alkene:

Consider a four-carbon chain with a double bond at the beginning:

```
CH2=CH-CH2-CH3
```

1. Longest Chain: The longest chain has four carbons, so the stem name is "but-".
2. Suffix: There is a double bond, so the suffix is "-ene".
3. Numbering: Count carbon-carbon bonds starting from the end closest to the double bond.
    - The double bond is between the first and second carbons.

Therefore, the name is but-1-ene.

Branch Rules

When dealing with branched organic molecules, follow these rules:

1. Name and Number Double or Triple Bonds First:
    - Prioritize identifying and numbering the position of double or triple bonds.
2. Identify and Name Alkyl Branches:
    - Alkyl branches are side chains consisting of carbon and hydrogen atoms (e.g., methyl, ethyl, propyl).
    - Indicate the position of each alkyl branch with a number corresponding to the carbon it is attached to.
    - Use the format: number-alkyl group name (e.g., 3-methyl).
3. Multiple Identical Alkyl Groups:
    - If there are two or more identical alkyl groups, use prefixes like di-, tri-, or tetra-.
    - Provide a number for each group's position.

    Example: 2,5-dimethyl indicates two methyl groups, one on the second carbon and another on the fifth carbon.
4. Different Alkyl Groups:
    - List different alkyl groups in alphabetical order.

    Example: If a molecule has both ethyl and methyl groups, list the ethyl group first because "e" comes before "m" in the alphabet.

TIE Breaker

When there's a tie in numbering, use alphabetic order to break the tie when getting to an alkyl group.

Dropping Unnecessary Numbers

If a number is the only possible number, it can be dropped.

> If there is only one possible position for a functional group, the number indicating its position is not necessary.

For example, consider ethene $(CH_2 = CH_2)$. There are two carbons, so it's "eth-", and it has a double bond, so it's an "-ene". If you followed all the rules, you would call it "eth-1-ene," but there is no way to have "eth-2-ene" since there isn't even a second carbon-carbon bond. Therefore, the correct name is ethene.

Prefixes for Repeated Alkyl Groups

When naming organic molecules, use the following prefixes to indicate the number of repeated alkyl groups:

Number of Groups	Prefix
2	di
3	tri
4	tetra

Example Naming

Let's name a complex molecule step-by-step:

1. **Find the Longest Chain**:
   - Identify the longest continuous carbon chain. In a complex molecule, this might require zig-zagging through the structure.
   - For example, the longest chain might be 10 carbons long (decane).
2. **Numbering the Chain**:
   - Determine the correct end to start numbering from to give the lowest numbers to the substituents.
3. **Identify and Name Substituents**:
   - Identify any alkyl or other substituents attached to the main chain.
4. **Combine and Name**:
   - Combine the substituent names with their positions and the main chain name.

Following the rules to name organic compounds ensures clarity and precision in chemical communication.

Naming Alkanes

Identifying Alkyl Groups

When naming alkanes, alkyl groups attached to the main carbon chain (the **stem**) need to be identified and named.

> Alkyl groups are substituents attached to the main carbon chain.

To identify alkyl groups, box them off, but remember that you can't include a carbon that is already part of the main carbon chain in an alkyl group. Alkyl groups that aren't connected to each other through the stem are considered separate.

For example, in **4,4-diethyldecane**, the two ethyl groups (two-carbon alkyl groups) are attached to the fourth carbon of the decane (ten-carbon) stem.

Determining the Correct Numbering

When multiple alkyl groups are present, it's important to number the carbon chain from the end that gives the **lowest possible numbers** to the substituents.

In the example of **4,4-diethyldecane**, numbering from the right end gives the numbers 4 and 4 for the ethyl groups, whereas numbering from the left would give 7 and 7, so the correct numbering is from the right.

Parent vs. Stem

The terms **parent** and **stem** are synonyms in the context of naming alkanes. They refer to the main carbon chain.

Methylpropane Example

Consider a molecule with a three-carbon chain (propane) and a methyl group attached. There's only one possible structure for methylpropane, which is **2-methylpropane**.

If the methyl group were on the end carbon (position 1), it would simply extend the main chain to four carbons, making it butane instead of methylpropane.

The fact that the methyl group is on the second carbon means that a number is not required, as the only possible methyl propane is in the two position. This is because:

Alkyl groups cannot be at the end of the chain, because if they were at the end, they would just be part of the chain and not a branch.

Alkenes and Alkynes: Drawing and Naming

Alkenes

- The **alkene** family is the second organic compound family we're learning about. Alkenes are hydrocarbons, meaning they contain only carbon and hydrogen.
- To be an alkene, a compound must have at least one **double bond** between carbon atoms. It's possible to have multiple double bonds (two would use the prefix "di-", three would use "tri-"), but we will focus on compounds with one double bond.
- Adding a double bond requires the removal of hydrogen atoms, leading to the term **unsaturated**.

  Unsaturated: An alkene is unsaturated with respect to hydrogen because it has fewer hydrogen atoms than a corresponding alkane with the same number of carbon atoms.

- Each double bond removes two hydrogen atoms (one from each carbon involved in the double bond). This unsaturation is where the term "unsaturated fats" comes from. Unsaturated fats contain double or triple bonds, affecting their melting and boiling points.

Naming Alkenes

1. **Identify the longest chain** that includes the double bond.
2. **Number the carbon atoms** in the main chain, starting from the end closest to the double bond.
    - The double bond is located between two carbon atoms, but we only need to specify the lower numbered carbon.
3. **Name the compound**:
    - Use the prefix corresponding to the number of carbons.
    - Replace the suffix "-ane" with "-ene" to indicate the presence of a double bond.
    - Include a number indicating the position of the double bond.
        - This number is necessary when there is more than one possible position for the double bond.

Example: Octene

Consider a molecule with eight carbon atoms (oct-) and a double bond (ene) at the second carbon:

$$CH_3 - CH = CH - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$$

The name of this compound is **oct-2-ene**.

Drawing Alkenes

Alkenes can be represented using three types of structures:

Structure Type	Description
Structural Formula	Shows all atoms and bonds.
Condensed Structure	Omits most or all bonds, grouping atoms together.
Line Structure	Represents carbon-carbon bonds as lines, with each end or intersection representing a carbon atom. Hydrogen atoms are not shown. Double bonds are indicated by doubling the line.

Example: Oct-2-ene

- Structural Formula: Shown above
- Condensed Formula: $CH_3CH = CHCH_2CH_2CH_2CH_2CH_3$
- Line structure:
    1. Draw the carbon backbone as a zig-zag line, with each corner or end representing a carbon atom. For octene, you would draw eight corners.
    2. Place the double bond between carbons two and three. Indicate the double bond by drawing two lines between the carbon atoms.
    3. Any rotation or mirror image of the line structure represents the same molecule.

Alkynes

- **Alkynes** are the third family of organic compounds. Like alkenes, they are hydrocarbons.
- Alkynes must have at least one **triple bond** between carbon atoms.
- Similar to alkenes, alkynes are unsaturated.
- Each triple bond requires the removal of four hydrogen atoms (two pairs) from an alkane.

Naming Alkynes

1. **Identify the longest chain** that includes the triple bond.
2. **Number the carbon atoms** in the main chain, starting from the end closest to the triple bond.
    - The triple bond is located between two carbon atoms, but we only need to specify the lower numbered carbon.
3. **Name the compound**:
    - Use the prefix corresponding to the number of carbons.
    - Replace the suffix "-ane" with "-yne" to indicate the presence of a triple bond.
    - Include a number indicating the position of the triple bond.
        - This number is necessary when there is more than one possible position for the triple bond.

Example: Pentyne

Consider a molecule with five carbon atoms (pent-) and a triple bond (yne) at the second carbon:

$$CH_3 - C \equiv C - CH_2 - CH_3$$

The name of this compound is **pent-2-yne**.

Drawing Alkynes

Similar to alkenes, alkynes can be represented using structural, condensed, and line structures. The key difference is the presence of a triple bond, which is shown as three lines in the structural and line structures.

Example: Pent-2-yne

- Structural Formula: Shown above
- Condensed Formula: $CH_3C \equiv CCH_2CH_3$
- Line structure:
    1. Draw the carbon backbone as a zig-zag line, with each corner or end representing a carbon atom. For pentyne, you would draw five corners.
    2. Place the triple bond between carbons two and three. Indicate the triple bond by drawing three lines between the carbon atoms.
    3. Any rotation or mirror image of the line structure represents the same molecule.

Additional Notes

- When naming alkenes and alkynes, it's best to name the compound yourself first before looking at answer choices. This avoids being biased by distractors.
- Any rotation of a molecule is the same thing.

Triple Bond Placement

When naming molecules with triple bonds, the position of the triple bond is indicated by a number. For example, if a triple bond is two carbons from the end of a six-carbon chain, it is correctly placed. A molecule and its mirror image are considered the same. It's like rotating a person 180 degrees; they're still the same person, even if their appearance changes slightly. Recognizing that flipped drawings can represent the same molecule requires practice.

Drawing Molecules from IUPAC Names

To draw molecules from their IUPAC names, follow this order:

1. Parent/Stem: Determine the number of carbons in the main chain.
2. Ending: Identify the type of bonds (single, double, triple).
3. Prefix: Add the alkyl groups.

Example: 2-methylhexane

1. Hexane indicates six carbons. Draw six carbons in a line: `C-C-C-C-C-C`.
2. The ending "ane" means all single bonds.
3. "2-methyl" means a methyl group (`CH_3`) is attached to the second carbon. Add it in:

   ```
         CH_3
         |
   C - C - C - C - C - C
   ```

4. Add hydrogens to each carbon to fulfill its four-bond capacity.

Mirror Images

Starting numbering from either end can yield correct, identical structures. But, if multiple alkyl groups are present, stick to one side when numbering.

Carbon Bonding Capacity

Remember, every carbon atom must have four bonds. Add hydrogen atoms as needed to satisfy this requirement. This is a reminder from Chem 20.

Practice Problems Recap

Problem B: Dimethylpropane

This problem emphasizes the importance of order.

- **Stem**: Propane (3 carbons)
- **Ending**: "ane" (all single bonds)

  So, you have `C-C-C`.

- **Prefix**: Dimethyl (two methyl groups)

  The trick is where to put them. You can't put methyl groups on the end carbons because that would just extend the main chain to butane.

```
Incorrect: C-C-C-C  (This is butane, not methylpropane)
```

  The only place to put both methyl groups is on the central carbon. The name becomes 2,2-dimethylpropane, but the "2,2" is often dropped because it's implied.

```
      CH_3
      |
C - C - C
      |
      CH_3
```

  There are different ways to draw it (one methyl group up, one down, or both up), but the connections are the same.

Problem C: Propene

- **Stem**: Prop (3 carbons)
- **Ending**: "ene" (one double bond)

  With no number given, the double bond is assumed to be in the 1-position. This means it's on one end of the three-carbon chain.

```
C = C - C  or  C - C = C
```

  Both are correct and equivalent. "Prop-2-ene" is incorrect because it doesn't minimize the number.

Harder Examples

For more complex molecules like the one in problem D, the same principles apply, just with more steps.

Example: Non-1-ene, 3-ethyl, 4-ethyl, 2-methyl

1. **Nonene**: Indicates 9 carbons with one double bond. The "1-ene" means the double bond is on the first carbon.

2. **Alkyl Groups**:

    - 3-ethyl: An ethyl group (`CH_2CH_3`) on the third carbon.
    - 4-ethyl: An ethyl group on the fourth carbon.
    - 2-methyl: A methyl group (`CH_3`) on the second carbon.

Failing is OK

It's normal to struggle when learning organic chemistry. Failure is a critical part of the learning process. Don't be discouraged by mistakes; learn from them.

Summary of First Three Families

We have summarized drawing molecules from the names of the first three families.

Drawing Organic Compounds

This guide covers how to draw organic compounds from the **-ane**, **-ene**, and **-yne** families using structural, condensed, and line diagrams.

Alkanes (-ane)

Example: Butane (C_4H_{10})

- **But-**: Indicates four carbons.
- **-ane**: Indicates all single bonds.
- General formula for alkanes: C_nH_{2n+2}

Structural Formula

Shows all bonds between atoms. For butane, connect four carbons with single bonds, then fill in the remaining bonds on each carbon with hydrogen atoms to satisfy the octet rule.

Condensed Formula

Summarizes the number of atoms around each carbon. For butane: $CH_3CH_2CH_2CH_3$

- The first carbon (CH_3) has three hydrogens.
- The two middle carbons (CH_2) each have two hydrogens.
- The last carbon (CH_3) has three hydrogens.

Line Diagram

A simplified representation where carbon atoms are at the end of each line segment and at each vertex (zig-zag). Hydrogen atoms are not explicitly drawn.

1. Draw a zig-zag line with four segments (representing the four carbons).
2. Each end and vertex represents a carbon atom.
3. The number of implied hydrogens is determined by bonding capacity.

Alkenes (-ene)

Example: But-1-ene (C_4H_8)

- But-: Indicates four carbons.
- -ene: Indicates the presence of a double bond.
- 1-ene: Indicates the double bond starts at the first carbon.
- General formula for alkenes: C_nH_{2n}

Structural Formula

Draw four carbons, with a double bond between the first and second carbon. Fill in the remaining bonds with hydrogen atoms.

Condensed Formula

$CH_2CHCH_2CH_3$

- The first carbon (CH_2) has two hydrogens due to the double bond.
- The second carbon (CH) has one hydrogen.
- The remaining carbons are saturated.

Line Diagram

Similar to alkanes, but a double line indicates the double bond.

1. Draw a zig-zag line with four segments.
2. Add a second line to the first segment to indicate the double bond between the first and second carbon.

Alkynes (-yne)

Example: Propyne (C_3H_4)

- **Prop-**: Indicates three carbons.
- **-yne**: Indicates the presence of a triple bond.
- General formula for alkynes (with one triple bond): C_nH_{2n-2}

Structural Formula

Draw three carbons, with a triple bond between the first and second carbon. Fill in the remaining bonds with hydrogen atoms.

Condensed Formula

CH_3CCH

- The first carbon (CH_3) has three hydrogens.
- The second carbon (C) has no hydrogens.
- The third carbon (CH) has one hydrogen.

Line Diagram

Similar to alkenes, but three lines indicate the triple bond. The molecule appears straight in the area with the triple bond due to the linear geometry.

1. Draw a line with three segments, but draw the first segment with three lines in parallel, indicating a triple bond.
2. Because of the geometry of triple bonds, the molecule is often drawn "straight" to reflect proper bond angles.

Key Concepts

> **Structural Formula:** A representation of a molecule that shows all atoms and the bonds connecting them.
>
> **Condensed Formula:** A simplified representation that lists atoms attached to each carbon, but omits most bonds.
>
> **Line Diagram:** A highly simplified representation where carbons and most hydrogens are implied, showing only the carbon skeleton and functional groups.

Saturated vs. Unsaturated: Saturated compounds (alkanes) have the maximum number of hydrogens, while unsaturated compounds (alkenes and alkynes) have fewer hydrogens due to the presence of double or triple bonds.

Summary Table

Feature	Alkane (Butane)	Alkene (But-1-ene)	Alkyne (Propyne)
Suffix	-ane	-ene	-yne
Bond Type	Single	Double	Triple
General Formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}
Example	$CH_3CH_2CH_2CH_3$	$CH_2CHCH_2CH_3$	CH_3CCH
Hydrogen Content	Saturated	Unsaturated	Unsaturated
window.MathJax = {			

```
tex: {
  inlineMath: [['$', '$'], ['\\(', '\\)']],
  displayMath: [['$$', '$$'], ['\\[', '\\]']]
}
```

};

Cyclic Alkanes and Alkenes

Naming Cyclic Hydrocarbons

Hydrocarbons can form **ring structures**. To name them, add "cyclo" to the front of the stem. This indicates to the reader that the structure is a ring, not a straight chain.

- **IUPAC** (International Union of Pure and Applied Chemistry) dictates that if a ring has a double bond, that double bond is in the **one position**.
- Minimize numbers going around the circle.

Cyclic Alkane Naming Example

Consider a cycloalkane with all single bonds in the ring structure.

1. The **ring** must be the **stem** or parent. Do not dig in and out of the ring.

2. Name it like before but add cyclo.

    - Example: A five-carbon ring with all single bonds is cyclopentane.

Cyclic Alkene Naming Example

Consider a cyclic alkene with a double bond and two alkyl (side) groups.

1. Find the **stem** or the **parent**.
2. Deal with the **ending**
3. Deal with the **branches**.
    - The ring is the parent.
        - Example: A five-carbon ring with a double bond is a cyclopentene.
4. IUPAC says the double bond has to be the **first carbon-carbon bond** in our counting.
5. Box up branches. If the branches are the same, name them together using prefixes like "di," "tri," or "tetra".
    - If the branches are different, list them alphabetically.
6. Minimize the numbers when numbering around the ring:
    - Consider both ways to go around the circle and minimize the count.
    - The first and second carbon MUST be on either side of the double bond
        - If you do not cross the double bond when numbering, it is incorrect.

Example:

A cyclopentene ring with two methyl branches:

- There are two ways to number this: Across the double bond counterclockwise, or across the double bond clockwise.
- The correct way to number this ring minimizes the numbers.
- The systematic name of this molecule is 3,4-dimethylcyclopentene

Generic Formulas and Patterns for Hydrocarbon Groups

There are generic patterns or formulas associated with the first five hydrocarbon groups.