Historical Ideas

Chemicals from living things were thought to contain a “vital force” that could not be duplicated in the lab. This changed with Friedrich Wöhler who mixed cyanic acid (HCNO) with ammonium hydroxide making ammonium cyanate (NH₄CNO).

\[
\text{urea}
\]

He usually allowed the salt solution to evaporate overnight, but tried heating it to hurry the process. The result was a crystal that he recognized as urea (H₂NCONH₂).

The modern view of organic chemistry is the chemistry of carbon compounds. C is the key element. It can form four bonds and that are very strong bonds due to its small size.

Alkanes (paraffins) follow the formula: CₙH₂ₙ₊₂;

These molecules contain ONLY single bonds. They are said to be saturated with hydrogens.

Memorize these prefixes also used with alkenes & alkynes.

- CH₄ methane
- C₂H₆ ethane
- C₃H₈ propane
- C₄H₁₀ butane
- C₅H₁₂ pentane
- C₆H₁₄ hexane
- C₇H₁₆ heptane
- C₈H₁₈ octane
- C₉H₂₀ nonane
- C₁₀H₂₂ decane

Given a formula, you can tell that it contains only single bonds because it fits the alkane formula.

Dichloromethane can be drawn using a structural formula.

This can be misleading. The molecule is not flat with bond angles of 90°. You must be aware of the 3-D structure and the 109.5° bond angles.

For example, there is only one isomer of dichloromethane, but you can draw it at least two ways.

Building models of the molecules is an important part of strengthening this skill.

Alkenes contain 1 double bond. The formula is CₙH₂ₙ. They are said to be “unsaturated” (like unsaturated fats). The double bond can be broken and more hydrogens added. Since double bonds cannot easily rotate (due to the pi bonding) cis- and trans-isomers can be formed.

Example: 1,2-dichloroethene can be built two ways.

<table>
<thead>
<tr>
<th>cis-1,2-dichloroethene (a polar molecule)</th>
<th>trans-1,2-dichloroethene (a nonpolar molecule)</th>
</tr>
</thead>
</table>

 Structural Formulas Can Be Misleading

Alkenes and cis- /trans- Isomerism
Alkynes contain 1 triple bond (unsaturated). Formula: \( C_nH_{2n-2} \). Ethyne (acetylene) is linear, so no cis/trans isomerism occurs.

Alkadienes are molecules with two double bonds. They have the same formula as the alkynes, \( C_nH_{2n-2} \).

Example: \( C_4H_6 \) is named 1,3-butadiene because the double bonds start on carbons #1 and #3.

Cyclic compounds contain rings having the same formula as the alkenes, \( C_nH_{2n} \).

Example: cyclopropane, \( C_3H_6 \).

The basic idea is to name the molecule after the longest continuous chain of carbon atoms. Side groups are listed with #’s to indicate the C atom to which they are attached.

**Side Groups:**
- \(-Cl\) chloro
- \(-Br\) bromo
- \(-I\) iodo
- \(-CH_3\) methyl
- \(-C_2H_5\) ethyl
- \(-C_3H_7\) propyl, etc.

- \( di\) = 2 groups
- \( tri\) = 3 groups
- \( tetra\) = 4 groups

**2,2,3-tribromobutane** (not 2,3,3-)

Note that we # the carbons from whichever end results in the smallest numbers.

While drawing the isomers of pentane, \( C_5H_{12} \), students draw this structure, naming it 2-ethylpropane. (a chain of 3 C’s with an ethyl group) The longest chain is four C’s, and should be named 2-methylbutane.

A similar error is to draw and name “1-methylsomething”. Two more tips…

- Double check that each C has four and only four bonds.
- Also, remember that N and O atoms have lone pairs of e−’s although they are seldom drawn. (Impt. for steric #!)

Some molecules have the ability to rotate polarized light. These molecules can be recognized by a C atom (the chiral carbon) bonded to four different groups.

3-methylhexane

This carbon is bonded to H, methyl, ethyl, & propyl groups. You can build two versions of this molecule that are “nonsuperimposable mirror images” of each other.” One will rotate light clockwise, one counterclockwise.

In biology, these are called dextro- and levo- (D and L) forms.
Common Names You Should Know About
(9 of 16)

- Ethene is also called ethylene.
- Propene is also called propylene.
- 2-Methylbutane is also called isopentane.
- "Iso-" means the same... the same two methyl groups come branch from C #2.
- 2-Methylpentane is isohexane, etc.
- 2,2-Dimethylpropane is called neopentane.

These common names show up occasionally in names... such as in isopropyl alcohol.

Aromatic Compounds
Benzene and its Derivatives
(10 of 16)

Benzene, C₆H₆, is unique. It can be drawn as shown, but the actual structure involves a circular pi bond (sp² orbitals & delocalized e⁻'s).

Two resonance structures

Benzene is also shown with a circle as the pi bond.

The carbon #s can be used for substituted benzene. Example: dichlorobenzene
1,2- is known as the ortho- position
1,3- is known as the meta- position
1,4- is known as the para- position

Paradichlorobenzene: the main ingredient in some moth balls.

Functional Groups I
Alcohols and Ethers
(11 of 16)

Alcohols
General formula: \( R-O-H \)  

\[ \text{C atoms are classified as primary (1), secondary (2), or tertiary (3) by the number of C atoms it is bonded to.} \]

A primary alcohol has the -OH group bonded to a primary carbon, etc.

This is not a base because the -OH is covalent, not ionic.

Naming: group + "alcohol" (e.g. ethyl alcohol or ethanol)

Ethers
General formula: \( R-O-R' \)  

\[ \text{[R' can = R, but not H]} \]

Naming: two groups + "ether"

diethyl ether was the 1st effective surgical and dental anesthetic.

Functional Groups II
Aldehydes and Ketones
(12 of 16)

Aldehydes
General formula: \( R-\overset{\text{O}}{\text{H}} \)

Naming: names end in "al" or "aldehyde"

methanaldehyde (formaldehyde)

Ketones
General formula: \( R-\overset{\text{O}}{\text{R'}} \)

Naming: names end in "one" or "ketone"

propanone (acetone)

Aldehydes and ketones both have a C=O group (carbonyl group). Aldehydes have it on an end carbon. Ketones have it on a middle carbon. Reactions: Primary alcohols can be oxidized into aldehydes. Secondary alcohols into ketones.
Carboxylic Acids and Esters

### Carboxylic Acids

- **General formula:** \( \text{R} \text{C} \text{O} \text{H} \)
- **Naming:** names end - "oic acid"
  - Ethanoic acid (acetic acid)
- **Reactions:** Acids can be made by oxidizing aldehydes.

### Esters

- **General formula:** \( \text{R} \text{C} \text{O} \text{R} \)
- **Naming:** names end - "ate"
  - Ethyl acetate (acetic acid + ethyl alcohol)
- **Reactions:** Esters are formed ("esterification") from a carboxylic acid & an alcohol. Water is removed (a "condensation" reaction). Esters often have pleasant, agreeable odors (e.g. banana.)

#### Amines & Amides

- **General formula:** \( \text{R} \text{N} \text{H} \)
- **Naming:** names contain "amino" or end in "amine"
  - Aminomethane (methylamine)
- **Amides**
- **Naming:** names end in "amide"
  - Acetamide

The N may have 1 or 2 or all 3 H atoms replaced with groups. The lone pair on the N atom makes these molecules basic. Your body needs certain amines "vital amines" = "vitamins."

### Polymers I

- **Monomers & Addition Polymerization**

  - **Monomer = one part**
  - **Polymer = many parts**

  - Ethylene
  - One kind of polymer is made up of monomers that contain a double bond.
  - The double bond can break and we can ADD to it… "Addition polymerization."

  \[
  \begin{array}{c}
  \text{H-CH=CH-} \\
  \text{H} \\
  \end{array} + \begin{array}{c}
  \text{CH=CH} \\
  \text{H} \\
  \end{array} \rightarrow \begin{array}{c}
  \text{H-CH-CH-} \\
  \text{H} \\
  \end{array}
  \]

  Different monomers form different polymers. This polymer would be called polyethylene. Replace on H on the monomer with Cl and you can make polyvinyl chloride, "PVC."

### Polymers II

- **Copolymers & Condensation Polymerization**

  - Another polymerization involves **condensation reactions.**

  - A di-acid & a di-alcohol (a glycol)
  - Esters form from an acid & an alcohol. Using a di-acid and a di-alcohol, you can make a continuous chain by removing water molecules. The resulting polymer is called a polyester.
  - Soda bottles are made from a polyester, polyethylene terephthalate ester (PETE).
  - Nylon (a polyamide) can be made from a di-amine & a di-acid.