20.1 Organic Chemistry

An Introduction to nomenclatures, structures and reactions

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Chemistry 201
Miramar College
Outline

Organic Chem and the Carbon atom
Atoms in Organic Compounds; Number of bonds
Representing Organic Compounds
Family Tree and Formula
Prefixes and suffixes
Degrees of Carbon
Isomers
Alkyl Group
IUPAC nomenclature
Substituents
Alkenes and Alkynes
  ... geometric isomers
Aromatic compounds and nomenclature
Functional Group
What is Organic Chemistry?

Organic Chemistry:
Study of carbon containing compounds.
Everything else is considered inorganic.
Over 30 million chemicals from 120 known elements.
800 thousands are inorganic the rest are organic chemicals.

Why are there so many organic compounds?
The magic Carbon atom

Difference between organic and inorganic is C-atom ability to form very long chain

Inorganic compound will become unstable after with 12 or more atoms.
C-atoms ability to form very strong covalent bond means molecules can possess 100 or more atoms
Evolution of Organic Chemistry

“Can man artificially create a living animal from chemicals?”

- magnitude of question concerning organic compound

Prior to 1828, organic compounds can only be obtained from living organism

Fredrick Wohler prepared urea, a chemical in urine (an organic compound)

\[
\text{NH}_4\text{Cl} + \text{AgNCO} \rightarrow \text{NH}_2\text{-CO-NH}_2 + \text{AgCl}
\]

Now a days the bulk of organic compounds is manufactured in the lab.
Source of Organic Compound

Organic chemicals isolate from nature. Nature has her huge laboratory and is constantly synthesizing chemicals through biosynthesis. Today we can manufacture these same chemicals in the lab.

- Mescaline
- Caffeine
- Ethanol
- Tetrahydrocannabinol THC
# Lewis Dot Structure: Number of bonds for nonmetal atom

## Lewis Dot Structure and VSEPR: revisited

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Val. e⁻</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td># Bonds</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>H-H</td>
<td>CH₄</td>
<td>NH₃</td>
<td>H₂O</td>
<td>H-Cl</td>
</tr>
</tbody>
</table>

![Lewis Dot Structures](image)
Forms of Carbons

Carbons with single bond:

- Methane, $\text{CH}_4$
  - Tetrahedral
  - $109.5^\circ$
  - sp$^3$

Carbons with double bonds:

- Ethene, $\text{C}_2\text{H}_6$
  - Trig. planar
  - $120^\circ$
  - sp$^2$

Carbons with triple bonds:

- Ethyne, $\text{C}_2\text{H}_2$
  - Linear
  - $180^\circ$
  - sp
Structure - Ways of presenting organic Compounds

Consider: Ethanol and dimethylether $C_2H_6O$

- **Molecular formula** - indicate type and number of atoms
  
  $C_2H_6O$  
  $C_2H_6O$

- **Structure formula** - shows connectivity of atoms in a compound

  Ethanol  
  Dimethylether

- **Condense formula** - shows connecting group of atoms in a compound

  Ethanol, $CH_3CH_2OH$  
  Dimethylether, $CH_3OCH_3$

- **Shorthand notation** - shows hydrocarbon as "R" and functional group as is.

  Ethanol $R$-OH  
  Dimethylether $R$-O-$R'$

- **Stick (Skeleton) form** - shows hydrocarbons as lines with functional group

  Ethanol  
  Dimethylether

- **Isomers** - Compounds that have the same formula but different structures

  Ethanol and dimethylether have the same formula but are different compounds and therefore possesses different properties

  Ethanol is the drinkable alcohol,  
  while dimethyl ether was used as an anesthetic.
# Functional Group

<table>
<thead>
<tr>
<th>Name</th>
<th>-Suffix</th>
<th>group</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aliphatics</td>
<td>-ane, -ene, -yen</td>
<td>(-\text{C}_\text{C}, \text{C}==\text{C})</td>
<td><img src="image" alt="propane" />, <img src="image" alt="propene" />, <img src="image" alt="proyne" /></td>
</tr>
<tr>
<td>Alcohol</td>
<td>-ol</td>
<td>(-\text{OH})</td>
<td><img src="image" alt="propanol" /></td>
</tr>
<tr>
<td>Ether</td>
<td>- ether</td>
<td>(\text{R}-\text{O}-\text{R}')</td>
<td><img src="image" alt="ethylpropylether" /></td>
</tr>
<tr>
<td>Aldehydes</td>
<td>-al</td>
<td>(\text{R}-\text{C}==\text{O})</td>
<td><img src="image" alt="propanal" /></td>
</tr>
<tr>
<td>Ketones</td>
<td>-one</td>
<td>(\text{R}-\text{C}=\text{R}')</td>
<td><img src="image" alt="propanone" /></td>
</tr>
<tr>
<td>Carboxylic acid</td>
<td>-oic acid</td>
<td>(\text{R}-\text{C}=\text{OH})</td>
<td><img src="image" alt="propanoic acid" /></td>
</tr>
<tr>
<td>Ester</td>
<td>-ate</td>
<td>(\text{R}-\text{C}==\text{O}-\text{R}')</td>
<td><img src="image" alt="methyl propanoate" /></td>
</tr>
<tr>
<td>amine</td>
<td>-amine</td>
<td>(\text{R}'\text{N}\text{R}')</td>
<td><img src="image" alt="triethyl amine" /></td>
</tr>
<tr>
<td>amide</td>
<td>-amide</td>
<td>(\text{R}-\text{C}==\text{N}\text{R}')</td>
<td><img src="image" alt="N-methylpropamide" /></td>
</tr>
</tbody>
</table>
Organic Compounds; the Family Tree.

- **Hydrocarbons**
  - Aliphatics
    - Alkane
    - Alkene
    - Alkyne
  - Cyclo Aliphatics

- **Heteroatoms**
  - Aromatic
The Alkanes

Alkanes $C_nH_{2n+2}$

Hydrocarbons with only single bonds

Methane $CH_4$

Ethane $C_2H_6$

Propane $C_3H_8$

Butane $C_4H_{10}$

Pentane $C_5H_{12}$
Degree of Carbon

[Chemical structure image]

- Degree of Carbon refers to the number of substituents attached to a carbon atom.
- The image shows a molecular structure with various substituents attached to a central carbon atom.
- The image helps illustrate the concept of degree of carbon in organic chemistry.

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**Organic Chemistry**

January 13
Degree of Carbon

a) primary carbons, 1° -
   carbons bonded to only one other carbon

b) secondary carbons, 2° -
   carbons bonded to two other carbons

c) tertiary carbons, 3° -
   carbons bonded to three other carbons

d) quaternary carbons, 4° -
   carbons bonded to four other carbons
# Prefix and the Number of Carbons

<table>
<thead>
<tr>
<th># of C</th>
<th>Molecular Formula</th>
<th>Prefix</th>
<th>Alkane name</th>
<th>Structure and isomers</th>
<th>group name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH₄</td>
<td>meth-</td>
<td>methane</td>
<td>CH₄</td>
<td>methyl</td>
</tr>
<tr>
<td>2</td>
<td>C₂H₆</td>
<td>eth-</td>
<td>ethane</td>
<td></td>
<td>ethyl</td>
</tr>
<tr>
<td>3</td>
<td>C₃H₈</td>
<td>prop-</td>
<td>propane</td>
<td></td>
<td>propyl, i-propyl</td>
</tr>
<tr>
<td>4</td>
<td>C₄H₁₀</td>
<td>but-</td>
<td>butane</td>
<td></td>
<td>butyl, iso-butyl, sec-butyl, tert-butyl</td>
</tr>
<tr>
<td>5</td>
<td>C₅H₁₂</td>
<td>pent-</td>
<td>pentane</td>
<td></td>
<td>pentyll</td>
</tr>
<tr>
<td>6</td>
<td>C₆H₁₄</td>
<td>hex-</td>
<td>hexane</td>
<td></td>
<td>etc...</td>
</tr>
<tr>
<td>7</td>
<td>C₇H₁₆</td>
<td>hept-</td>
<td>heptane</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>C₈H₁₈</td>
<td>oct-</td>
<td>octane</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>C₉H₂₀</td>
<td>non-</td>
<td>nonane</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>C₁₀H₂₂</td>
<td>dec-</td>
<td>decane</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Isomers are molecules with the same chemical formula but different structural formula.

### Pentane \((C_5H_{12})\)

<table>
<thead>
<tr>
<th></th>
<th>n-pentane</th>
<th>iso-pentane</th>
<th>neo-pentane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="structure1.png" alt="Structure" /></td>
<td><img src="structure2.png" alt="Structure" /></td>
<td><img src="structure3.png" alt="Structure" /></td>
</tr>
</tbody>
</table>

### Hexane \((C_6H_{14})\)

<table>
<thead>
<tr>
<th></th>
<th>n-hexane</th>
<th>2-methylpentane</th>
<th>3-methylpentane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="structure4.png" alt="Structure" /></td>
<td><img src="structure5.png" alt="Structure" /></td>
<td><img src="structure6.png" alt="Structure" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2,3-dimethylbutane</th>
<th>2,2-dimethylbutane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="structure7.png" alt="Structure" /></td>
<td><img src="structure8.png" alt="Structure" /></td>
</tr>
</tbody>
</table>
Alkyl group (in naming scheme)

Alkyl group - An important idea in the naming scheme is the group of atoms attached to a carbon chain. These have yl - suffix.

methane → methyl
ethane → ethyl

First 5 alkyl groups and their isomers:

1. Methyl
   ![Stick figure of methyl]

2. Ethyl
   ![Stick figure of ethyl]

3. Propyl: n-propyl, isopropyl
   ![Stick figure of n-propyl]
   ![Stick figure of isopropyl]

4. Butyl: n-butyl, sec-butyl, iso-butyl, tert-butyl
   ![Stick figure of n-butyl]
   ![Stick figure of sec-butyl]
   ![Stick figure of iso-butyl]
   ![Stick figure of tert-butyl]

5. Pentyl: n-pentyl, sec-pentyl, iso-pentyl, neo-butyl

(Assignment, write the stick figures of these alkyl groups)
IUPAC Nomenclature

Rules of the game:

Alkane \((C_nH_{2n+2})\)

1. Find the **longest continuous chain** of carbon atoms. Assign this chain as the parent name.
2. Determine the **substituents (groups)** attached to the parent chain.
3. Assign **attachment position** of group to main chain by starting at end closest to substituent group (or lowest number position).*
4. Identical groups attached to the main chain are designated with prefixes.
   - 2-di, 3-tri, 4-tetra, 5-penta
5. Different groups attached to main chain are written in **alphabetical order**.
6. Alkyl halides: Halogen atoms (group) are designated as halogen prefix.
   - F - Fluoro, Cl-Chloro, Br- Bromo, I- Iodo
7. Alkyl groups (see previous page)

* The numbering scheme should be chosen such that the sum of the position in which group are attached add up to the lowest sum.

http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/nomen1.htm
IUPAC nomenclature, an example

Consider the following hexane compound:
Heptane (C\(_7\)H\(_{16}\))

1. Pentane
2. Methyl
3. Carbon \# 2 & \# 3
4. \(2,3\) = position methyl = group pentane = parent name
5. Two methyl, \(\rightarrow\) dimethyl
6. Name: \(2,3\)-dimethylpentane
Common substituents

• **Alkyl**
  - Methyl
  - Ethyl
  - Propyl: normal(n)-propyl, iso(i)-propyl
  - Butyl: normal(n)-butyl, iso(i)-butyl, sec(s)-butyl, tert(t)-butyl

• **Halogens**
  - Fluoro (F), Chloro (Cl), Bromo (Br), Iodo(I)

• **Others**
  - Nitro (NO$_2$), Hydroxyl (OH), cyano (CN),
Alkenes and Alkynes

Alkenes $C_nH_{2n}$

- Ethene, $C_2H_4$
- Propene, $C_3H_6$

Alkynes $C_nH_{2n-2}$

- Ethyne, $C_2H_2$
- Propyne, $C_3H_4$

Hydrocarbons with multiple bonds

Note:
If there is more than one multiple bond, it is unsaturated. i.e.,
More on Alkenes

Geometric Isomers

Cis 2-butene

Trans 2-butene

Can’t rotate the double bond which makes these molecules unique compounds or specifically, Geometric isomers.

Life example: 11-cis-retinal $\rightarrow$ all trans retinal

Visual pigment (rhodopsin) $\rightarrow$ Signals optic nerve cell

hv

dark

with enzyme
Nomenclature: Alkenes and Alkyne

more rules of the game:

Alkene \((C_nH_{2n})\) -ene (suffix)
1. -ene suffix for alkenes
2. Main chain must include the double bond, the number one carbon is the carbon closest to the double bond.
3. Position of double bond indicated by prefix numbering location.
4. For multiple double bonds:
   - di = 2 double bonds
   - tri = 3 double bonds

Alkyne \((C_nH_{2n-2})\) -yne (suffix)
1. -yne suffix for alkynes
2. Nomenclature rules are similar to that of alkenes
Aromatics: nomenclature

1. Monosubstituted
   a. group benzene
      - nitrobenzene
      - chlorobenzene
      - bromobenzene
      - ethylbenzene
   b. special names:
      - phenol
      - toluene
      - aniline
      - benzaldehyde

2. Two substituted groups
   - use prefix for position

3. Three substituted groups
   - requires # scheme (lowest position scheme)

4. Benzene as a group
   - phenyl
# Functional Group

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</thead>
<tbody>
<tr>
<td>1 Aliphatics</td>
<td>-ane, -ene, -yen</td>
<td>C–C, C=C, C≡C</td>
<td>propane, propene, proyne</td>
</tr>
<tr>
<td>2 Alcohol</td>
<td>-ol</td>
<td>–OH</td>
<td>–OH = propanol</td>
</tr>
<tr>
<td>3 Ether</td>
<td>- ether</td>
<td>R–O–R'</td>
<td>ethylpropylether</td>
</tr>
<tr>
<td>4 Aldehydes</td>
<td>-al</td>
<td>R–C≡O</td>
<td>propanal</td>
</tr>
<tr>
<td>5 Ketones</td>
<td>-one</td>
<td>R–C–R'</td>
<td>propanone</td>
</tr>
<tr>
<td>6 Carboxylic acid</td>
<td>-oic acid</td>
<td>R–C–OH</td>
<td>propanoic acid</td>
</tr>
<tr>
<td>7 Ester</td>
<td>-ate</td>
<td>R–C=O–R'</td>
<td>methyl propanoate</td>
</tr>
<tr>
<td>8 amine</td>
<td>-amine</td>
<td>R'–N–R'</td>
<td>triethyl amine</td>
</tr>
<tr>
<td>9 amide</td>
<td>-amide</td>
<td>R–C=O–N–R'</td>
<td>N-methylpropamide</td>
</tr>
</tbody>
</table>
What is the IUPAC names of the following alkanes:

![Structural formulas]

Draw the condensed structural formulas and the stick form for the following
i) 2,4-dimethyl-nonane
ii) 3-methyl-4,4-diethyl-trans-2-heptene
iii) 1-ethyl-4-methyl-cyclohexane:

Identify the functional group for each compound:

![Functional group examples]