Student Name: _______________________________________

Class Period: ________
Unit 13 Vocabulary:

1. Addition Reaction: Halogen atoms break the double or triple bond on an unsaturated hydrocarbon chain and bond to either side of where the bond was broken.
2. Alcohol: A hydrocarbon with an –OH (hydroxyl) group somewhere on the hydrocarbon chain.
3. Aldehyde: A hydrocarbon with a –CO (carbonyl) group containing a hydrogen (H) bonded to a primary chain carbon.
4. Alkane: A hydrocarbon with the general formula C\(_n\)H\(_{2n+2}\), where all the carbon-carbon bonds are single bonds.
5. Alkene: A hydrocarbon with the general formula C\(_n\)H\(_{2n}\), where only one of the carbon-carbon bonds is a double bond.
6. Alkyl Group: An alkane fragment substituted onto a primary hydrocarbon chain; e.g. methyl group.
7. Alkyne: A hydrocarbon with the general formula C\(_n\)H\(_{2n-2}\), where only one of the carbon-carbon bonds is a triple bond.
8. Allotrope: A molecular form of only one element. Oxygen has two allotropes; O\(_2\) (diatomic oxygen), and O\(_3\) (ozone).
10. Amine: A hydrocarbon with a –N= (amine) group substituted onto the primary hydrocarbon chain.
11. Combustion: A form of reaction where a hydrocarbon reacts with oxygen to form the products of carbon dioxide (CO\(_2\)) and water (H\(_2\)O). Also known as burning; is a highly exothermic reaction.
12. Dehydration Synthesis: The joining of two organic molecules by the removal of an –H from one molecule an –OH from the other molecule, forming an HOH (water) molecule in the process.
13. Ether: A molecule of two hydrocarbon chains connected by a single oxygen molecule (–O–) between the two chains.
15. Esterification: The dehydration synthesis of an ester be reacting an organic acid with a primary alcohol.
17. Fermentation: The anaerobic (without oxygen) respiration of simple sugars by yeast to produce ethanol and carbon dioxide.
18. Halocarbon: A hydrocarbon that has one (or more) halogen (Group 17) atoms substituted or added to a hydrocarbon chain.
20. Isomer: Molecules with the same molecular formula, but different structural (shape) formulas.
22. Monomer: A single molecule, usually an alkene, alkadiene, or diol and dicarboxylic acid.
23. Organic Acid: A hydrocarbon with a −COOH (carboxyl) group bonded to a primary carbon.
24. Polymer: A long chain of connected monomer units. A few examples include: rayon, silk, polypropylene, polyvinyl chloride (PVC) plastic, and polystyrene (plastic).
25. Polymerization: The joining of many monomer units by addition reactions or dehydration synthesis to form enormous macromolecules (polymers).
26. Primary: Positional description of a carbon atom on the end of a hydrocarbon chain that is only directly bonded to another carbon atom.
27. Saponification: The hydrolysis of a glycerol ester (fat) by a strong base to form glycerol and soap.
29. Secondary: Positional description of a carbon in within a hydrocarbon chain that is bonded to two other carbons.
30. Substitution Reaction: Halogen (Group 17) atoms replace hydrogen atoms on a saturated hydrocarbon chain.
31. Tertiary: Positional description of a carbon atom within a hydrocarbon chain that is directly bonded to three other carbon atoms.
32. Unsaturated Hydrocarbon: A hydrocarbon with one or more double (or triple) carbon-carbon bonds.
## Unit 13 Homework Assignments:

<table>
<thead>
<tr>
<th>Assignment:</th>
<th>Date:</th>
<th>Due:</th>
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<tbody>
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</table>
Notes page:
Organic Chemistry:

- Organic chemistry is the study of how chemistry interacts with biological processes to allow life to exist on planet Earth. Without organic chemistry, none of us would be here.

- Organic chemistry is also one of those “love it” or “hate it” courses, and has been the turning point for many college students that were planning on medical or other life science careers. It usually is nicknamed “O-chem”, and saying that either generates smiles or grimaces from people you talk too.

- That being said, we will only scratch the surface of organic chemistry over the next week or so. In college, organic chemistry is a full YEAR (two semesters), including weekly 4+ hour labs. It is one of the most anticipated (dreaded?) courses in many college students’ education.

- Scared yet? Don’t be, but there is a reason we keep this topic until the end of the year. You’ll need to fall back and use ALL of your learned chemistry knowledge to date to tackle the wonderful (and daunting!) world of organic chemistry. Stick with me; we’ll get ‘er done!
Topic: **Studying Organic Chemistry**

Objective: What makes Organic Chemistry so special?

Organic Chemistry:

- **Organic** chemistry deals with the **chemistry** of **carbon** and **compounds** of carbon, most usually hydrocarbons (carbon and hydrogen compounds.)

The Chemistry of Carbon

![Methane, Acetylene, Butadiene, Benzene, Isooctane](image)

Carbon has 4 valence electrons, allowing it to bond to 4 other atoms

Carbon forms strong covalent bonds

Carbon bonds easily with other carbon atoms, hydrogen, oxygen, nitrogen, sulfur, and phosphorous =

**Organic Compounds** -

Organic compounds interact to perform the basic functions of life
Properties of Carbon Compounds:

- Carbon forms **four** covalent **bonds** that may be **single**, **double**, or **triple**. Carbon has four unpaired electrons in its ground state. The four unpaired **electrons** want to be as far **apart** from each other as possible, lending carbon to have a natural **tetrahedral** shape for bonding.

1. Most **organic** compounds are **nonpolar**, or weakly polar. As such, most organic compounds are held together by weaker **London Dispersion Force**s and therefore have:
   - i. Low melting and boiling points;
   - ii. High vapor pressures (volatile).
2. There are millions of known organic compounds, compared to about 60,000 known inorganic compounds. As diverse as life is, the number of organic compounds created by life may be as diverse.

3. Most organic compounds are insoluble in water, or immiscible (unmixable) in water.

4. Organic compounds easily undergo combustion with oxygen. Combustion is a form of reaction where a hydrocarbon (C & H) reacts with oxygen to form the products of carbon dioxide and water. One component of gasoline is the hydrocarbon octane, C₈H₁₈, here combusting with oxygen.

   \[ 2 \text{C}_8\text{H}_{18}(l) + 25 \text{O}_2(g) \rightarrow 16 \text{CO}_2(g) + 18 \text{H}_2\text{O}(g) \]

5. Organic compounds decompose with heat in anoxic (without oxygen) conditions to the elemental components. Fossil fuels (petroleum, coal) formed this way over millions of years.

6. Organic reactions are much more complex than inorganic reactions, and require a much longer time and more complex mechanisms to occur.
Hydrocarbons:

- Hydrocarbons are a class of organic molecules that contain ONLY *carbon* and *hydrogen*.
Reference Table Q, *Homologous Series of Hydrocarbons*, has the suffix information, formula, naming, and structural characteristics.

<table>
<thead>
<tr>
<th>Name</th>
<th>General Formula</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Name</td>
</tr>
<tr>
<td>alkanes</td>
<td>$C_nH_{2n+2}$</td>
<td>ethane</td>
</tr>
<tr>
<td>alkenes</td>
<td>$C_nH_{2n}$</td>
<td>ethene</td>
</tr>
<tr>
<td>alkynes</td>
<td>$C_nH_{2n-2}$</td>
<td>ethyne</td>
</tr>
</tbody>
</table>

*Note: $n =$ number of carbon atoms*

It was already mentioned that there are millions of organic compounds, and more being discovered every day. A naming system had to be developed to effectively handle the influx of new organic compounds. The International Union of Pure and Applied Chemistry (IUPAC) is responsible for chemical nomenclature (naming). The names of organic compounds are designed to describe a molecule in logical ways.

Watch Crash Course Chemistry Hydrocarbons YouTube video - 11:31

https://www.youtube.com/watch?v=UloIw7dhnIQ
How many carbons are in the longest continuous chain?

The **longest continuous chain** of carbons in the molecule gives the organic molecule its **prefix** for the **name** (Reference Table P).

<table>
<thead>
<tr>
<th># of Carbon atoms in longest chain</th>
<th>Prefix</th>
<th>Examples (only a <strong>FEW</strong>; not all inclusive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Meth-</td>
<td>Methane, methanol, methanoic acid</td>
</tr>
<tr>
<td>2</td>
<td>Eth-</td>
<td>Ethane, ethanol, ethyne, ethene, ethanoic acid</td>
</tr>
<tr>
<td>3</td>
<td>Prop-</td>
<td>Propane, propene, propyne, propanoic acid</td>
</tr>
<tr>
<td>4</td>
<td>But-</td>
<td>Butane, butanol, butyne, butene, butanoic acid</td>
</tr>
<tr>
<td>5</td>
<td>Pent-</td>
<td>Pentane, pentanol, pentyne, pentene, pentanoic acid</td>
</tr>
<tr>
<td>6</td>
<td>Hex-</td>
<td>Hexane, hexanol, hexyne, hexene, hexanoic acid</td>
</tr>
<tr>
<td>7</td>
<td>Hept-</td>
<td>Heptane, heptanol, heptyne, hexene, heptanoic acid</td>
</tr>
<tr>
<td>8</td>
<td>Oct-</td>
<td>Octane, octanol, octyne, octane, octanoic acid</td>
</tr>
<tr>
<td>9</td>
<td>Non-</td>
<td>Nonane, nonanol, nonyne, nonene, nonanoic acid</td>
</tr>
<tr>
<td>10</td>
<td>Dec-</td>
<td>Decane, decanol, decyne, decene, decanoic acid</td>
</tr>
</tbody>
</table>

**Saturated Hydrocarbons:**

i. A **saturated** hydrocarbon is a hydrocarbon that has all **single** bonds between the carbon atoms (C-C bonds).

ii. ALL alkanes are saturated hydrocarbons.
Regents Practice Problems-Carbon Compounds (ungraded):

1) Which compound must be present in an organic compound?
   a) Carbon  c) Nitrogen
   b) Oxygen  d) Hydrogen

2) Which structural formula below is incorrect?
   a) \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \quad \text{Cl}
   \end{array}
   \]
   b) \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \quad \text{C} \\
   \text{H}
   \end{array}
   \]
   c) \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \quad \text{O} \\
   \text{H}
   \end{array}
   \]
   d) \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \quad \text{C} \\
   \text{C} \quad \text{C} \\
   \text{H} \quad \text{H} \quad \text{H}
   \end{array}
   \]

3) What is the total number of pairs of electrons that one carbon atom shares with the other carbon atom in the molecule C₂H₄?
   a) 1  b) 2  c) 3  d) 4

4) An atom of which element can covalently bond with four other identical atoms?
   a) Carbon  c) Barium
   b) Oxygen  d) Fluorine

5) Which statement explains why the element carbon forms so many compounds?
   a) Carbon atoms combine readily with oxygen.
   b) Carbon atoms have a very high electronegativity.
   c) Carbon readily forms ionic bonds with other carbon atoms.
   d) Carbon readily forms covalent bonds with other carbon atoms.
Alkane Family:

1. The **simplest** form of **hydrocarbon** is the **alkane** series, also called the paraffin family. Alkanes are made up of a single chain of carbon-carbon (C-C) bonds with two (a middle carbon) or three (an end carbon) hydrogen (H) atoms attached to each carbon atom.

<table>
<thead>
<tr>
<th>FORMULA</th>
<th>Name</th>
<th>Boiling Point</th>
<th>Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>methane</td>
<td>-161 °C</td>
<td>![CH₄ structure]</td>
</tr>
<tr>
<td>C₂H₆</td>
<td>ethane</td>
<td>-89</td>
<td>![C₂H₆ structure]</td>
</tr>
<tr>
<td>C₃H₈</td>
<td>propane</td>
<td>-44</td>
<td>![C₃H₈ structure]</td>
</tr>
<tr>
<td>C₄H₁₀</td>
<td>butane</td>
<td>-0.5</td>
<td>![C₄H₁₀ structure]</td>
</tr>
<tr>
<td>C₅H₁₂</td>
<td>pentane</td>
<td>36</td>
<td>![C₅H₁₂ structure]</td>
</tr>
<tr>
<td>C₆H₁₄</td>
<td>hexane</td>
<td>68</td>
<td>![C₆H₁₄ structure]</td>
</tr>
<tr>
<td>C₇H₁₅</td>
<td>heptane</td>
<td>98</td>
<td>![C₇H₁₅ structure]</td>
</tr>
<tr>
<td>C₈H₁₈</td>
<td>octane</td>
<td>125</td>
<td>![C₈H₁₈ structure]</td>
</tr>
<tr>
<td>C₉H₂₀</td>
<td>nonane</td>
<td>151</td>
<td>![C₉H₂₀ structure]</td>
</tr>
<tr>
<td>C₁₀H₂₂</td>
<td>decane</td>
<td>174</td>
<td>![C₁₀H₂₂ structure]</td>
</tr>
</tbody>
</table>

Add 1 carbon and 2 hydrogens to the middle of pentane
Add 1 carbon and 2 hydrogens to the middle of hexane
Add 1 carbon and 2 hydrogens to the middle of heptane
Add 1 carbon and 2 hydrogens to the middle of octane
Add 1 carbon and 2 hydrogens to the middle of nonane
2. Look at the boiling point listed for each alkane group. As the molecule gets **larger**, the boiling point **increases**. This is due to the increasing number of London Dispersion forces, and with it more London Dispersion strength.

3. Methane (CH$_4$) is the only hydrocarbon that is **only** an alkane, since it only has one carbon atom.

4. The general **formula** for an **alkane** is C$_n$H$_{2n+2}$. If you know the number of carbon atoms (prefix), then you double the prefix and add two to get the number of hydrogen atoms for that alkane.

5. What is the molecular formula for octadecane? Well, this one is not on your chart, but octadec- is the prefix for 18, so this is an 18 carbon alkane. Using the general formula C$_n$H$_{2n+2}$, we can write the molecular formula for octadecane:

\[
18 \text{ carbons} = n \quad \rightarrow \quad C_{(18)}H_{(2 \times 18 + 2)} = C_{18}H_{38}
\]

**Unsaturated Hydrocarbons:**

i. An unsaturated hydrocarbon is a hydrocarbon that contains at least one double (C=C) or triple (C≡C) carbon to carbon bond.

ii. Unsaturated hydrocarbons are anything EXCEPT alkanes.
Alkene Family:

1. The alkene family, also known as the olefin family, differ from their related alkanes by having one carbon to carbon double bond ($\text{C}=\text{C}$) somewhere along the longest chain.
2. Ethane ($\text{C}_2\text{H}_4$) and propene ($\text{C}_3\text{H}_6$) are the smallest alkenes, and only form one structural shape.
3. Butene ($\text{C}_4\text{H}_8$) is the smallest alkene that may have isomers, which are the same molecular formula, but different structural (shape) formula. Any alkenes larger than butane have isomers.
4. The general formula for an alkene is $\text{C}_n\text{H}_{2n}$. If you know the number of carbon atoms (prefix), then you double the prefix to get the number of hydrogen atoms for that alkene.
5. What is the molecular formula for octadecene? This is an 18 carbon alkene. Using the general formula $\text{C}_n\text{H}_{2n}$, we can write the molecular formula for octadecene:

$$18 \text{ carbons} = n \Rightarrow \text{C}_{(18)}\text{H}_{(2 \times 18)} = \text{C}_{18}\text{H}_{36}$$
Ethene: 2 carbons with a double bond between them. Each carbon fills its remaining two bonds with hydrogens.

Propene: 3 carbons with a double bond between the end carbon and the middle carbon.

1-butene: there is a double bond between the end carbon (the 1st carbon) and the 2nd carbon. The number 1- indicates that the 1st carbon is the lowest numbered carbon that the double bond is touching.

2-butene: there is a double bond between the two middle (2nd and 3rd) carbons. The number 2- indicated that the 2nd carbon is the lowest numbered carbon that the double bond is touching.

1-pentene: there is a double bond between the 1st and 2nd carbons.

2-pentene: there is a double bond between the 2nd and 3rd carbons.

Also 2-pentene. Count the carbons from the side the double bond is closest to. In this case, it’s the right side, and the double bond is between the 2nd and 3rd carbons.
Alkyne Family:

1. The alkyn family differs from their related alkane by having one carbon to carbon triple bond (C≡C) somewhere along the longest chain.
2. Ethan (C₂H₂) and propyn (C₃H₄) are the smallest alkynes, and only form one structural shape.
3. Butyne (C₄H₆) is the smallest alkyne that may have isomers, which are the same molecular formula, but different structural (shape) formula. Any alkynes larger than butyne have isomers.
4. The general formula for an alkyne is CₙH₂n-2. If you know the number of carbon atoms (prefix), then you double the prefix to get the number of hydrogen atoms for that alkyne.
5. What is the molecular formula for octadecyne? This is an 18 carbon alkyne. Using the general formula CₙH₂n, we can write the molecular formula for octadecyne:

\[ 18 \text{ carbons} = n \quad \Rightarrow \quad C_{(18)}H_{(2 \times 18 - 2)} = C_{18}H_{34} \]
H – C ≡ C – H  ethyne: 2 carbons with a triple bond between them.

H – C ≡ C – C – H
  
propyne: 3 carbons with a triple bond between two of the carbon atoms

H – C ≡ C – C – C – H
  
1-butyn: 4 carbons with a triple bond between the first and second carbon

H – C – C ≡ C – C – H
  
2-butyn: 4 carbons with a triple bond between the second and third carbon

H – C ≡ C – C – C – C – H
  
1-pentyn: 5 carbons with a triple bond between the first and second carbons

H – C – C ≡ C – C – C – H
  
2-pentyn: 5 carbons with a triple bond between the second and third carbons

H – C – C – C ≡ C – C – H
  
Also 2-pentyn, this time the triple bond is between the second and third carbons in from the right side of the molecule.
Regents Practice Problems-Hydrocarbons (ungraded):

1. Which formula represents a saturated hydrocarbon?
   a) C₂H₂  b) C₂H₄  c) C₂H₆  d) C₄H₈

2. What is the general formula for the members of the alkane series?
   a) CₙH₂n  c) CₙH₂n+2
   b) CₙH₂n-2  d) CₙH₂n-6

3. Which structural formula represents an unsaturated hydrocarbon?

\[
\begin{align*}
\text{a)} & \quad \text{H} - \text{C} - \text{H} \\
\text{b)} & \quad \text{H} - \text{C} \equiv \text{C} - \text{H} \\
\text{c)} & \quad \text{H} - \text{C} = \text{C} - \text{H} \\
\text{d)} & \quad \text{H} - \text{C} - \text{C} - \text{H}
\end{align*}
\]

4. What is the correct formula for butane?
   a) C₄H₄  c) C₄H₈
   b) C₄H₆  d) C₄H₁₀

5. Given the structural formula for ethyne as: H-C≡C-H
   What is the total number of electrons shared between carbon atoms?
   a) 2  b) 3  c) 4  d) 6
Notes page:
Hydrocarbon Organic Chemistry homework

Multiple choice & fill-in questions: circle the correct answer choice. 1 pt. ea.

1. Which of the following compounds is formed by covalent bonding?
   a) LiH   b) Na₂S   c) AlCl₃   d) C₆H₁₂O₆

2. Which of the following substances is organic?
   a) CH₄   b) NH₃   c) H₂O   d) NaCl

3. Which of the following substances is insoluble in water?
   a) CH₄   b) NH₃   c) H₂O   d) NaCl

4. When two carbon atoms form a double bond, how many e⁻ pairs are shared between the two carbon atoms?
   a) 1   b) 2   c) 3   d) 4

5. Pentane has five carbon atoms. How many H atoms will it contain? _____

6. Pentene has five carbon atoms. How many H atoms will it contain? _____

7. Pentyne has five carbon atoms. How many H atoms will it contain? _____
**Name** each of the following compounds: 1 pt. ea.

1. 

2. 

3. 

4. 

**Draw** the **structural** formulas for the following compounds: 1 pt. ea.

<table>
<thead>
<tr>
<th>1. ethane</th>
<th>2. 1-butene</th>
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</thead>
<tbody>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>3. propyne</th>
<th>4. 2-hexene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Topic: **Substituted Hydrocarbons**

Objective: What happens to hydrocarbons with added groups?

**Substituted Hydrocarbons:**

- Substituted Hydrocarbons are simply any hydrocarbon that has an **atom** or a **functional group** (a certain combination of atoms that has a specific role) in **place** of a **hydrogen** atom on that hydrocarbon chain.

**International Union of Pure and Applied Chemistry (IUPAC) Naming System**

- The steps in the IUPAC naming system are as follow:
  1. The **number** of carbons in the **longest** continuous unbroken **chain** is used to determine the prefix of the parent molecule name. The longest continuous chain may **look** like it **bends** from a straight line;
  2. The **position** of any functional group on the longest chain is used for **two purposes**:
     a. Determining the **direction** of **numbering** for the carbons. A functional group is on the lowest possible numbered carbon;
     b. Determining the **suffix** of the parent molecule **name**.
  3. The position of any **alkyl** (alkane fragment) group is considered next. If no other functional groups are present, the alkyl group gets **priority** in numbering.
4. When two (or more) identical alkyl groups are present on the longest hydrocarbon chain, their number is specified by using Greek prefixes and specified position:
   i. di- = 2
   ii. tri- = 3
   iii. tetra- = 4, etc.

5. When different alkyl groups are present on the same chain, they are listed in alphabetical order (ethyl before methyl, methyl before propyl, etc.)

6. When halide (halogen) groups are on the chain, their names, numbers, and positions are considered last, listed in alphabetical order.
**Topic:** Naming Substituted H-carbons

**Objective:** How do we name substituted hydrocarbon molecules?

### Examples of Naming Substituted Hydrocarbons:

<table>
<thead>
<tr>
<th>Structure</th>
<th>Name</th>
</tr>
</thead>
</table>
| H - C - H | One carbon = methane  
One chloro group attached = chloro methane |
| H - C - Cl | One carbon = methane  
Two chloro groups attached = dichloro methane |
| H - C - H | Two C's single bonds = ethane  
One fluoro group attached = fluoro ethane |
| F - C - C - H | Two C's single bonds = ethane  
Two fluoro groups = difluoro |
| | Both F's on the end carbon  
1,1 difluoro ethane |
| F - C - C - F | Two C's w/ single bond = ethane  
2 F's attached, on the 1st and one on the 2nd carbon  
1,2 difluoro ethane |
| Br - C - Br - F | 2 C's w/ single bond = ethane  
Br's, one on the 1st and one on the 2nd = 1,2 dibromo |
| | 1 F on the end carbon  
1 fluoro 1,2 dibromo ethane |
| H - C - Cl - H | 3 carbons, single bonded = propane  
2 chloro groups, one on the 1st and one on the 2nd carbon |
| Cl | 1,2 dichloro propane |
| H - C - C - Cl | 3 carbons, single bonded = propane  
2 chloro groups, on the 1st and one on the 3rd carbon |
| Cl | 1,3 dichloro propane |
| H - C - H | 3 carbons, single bonded = propane  
1 methyl group on the middle carbon |
| | 2 methyl propane |
| H - C - C - H | Four carbons single bonded = butane  
Two methyl groups, both bonded to the second carbon in on the right side |
| | 2,2 dimethyl butane |

- As the number of carbon atoms increases, the more isomers (unique structural shapes) of that molecule increases greatly.
Addition and Substitution Reactions:

- Hydrocarbons undergo two simple types of reactions, the products of which are called hydrocarbon derivatives, hydrocarbon substitution products, or substituted hydrocarbons.

**The leading families of organic compounds**

- **Hydrocarbon**: Methane (CH₄)
- **Alcohol**: Methyl alcohol (CH₃OH)
- **Aldehyde**: Formaldehyde (HCHO)
- **Acid**: Formic acid (HCOOH)
- **Ester**: Ethyl formate (C₂H₅COOH)
- **Ether**: Diethyl ether (C₂H₅OC₂H₅)
- **Ketone**: Acetone (CH₃COCH₃)
- **Amine**: Methyl amine (CH₃NH₂)
- **Amide**: Acetamide (CH₃CONH₂)

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Substitution Reactions:

1. If a saturated hydrocarbon (an alkane) reacts with a halogen (Group 17), one of the hydrogen atoms on the hydrocarbon chain is replaced with a halogen. The replaced hydrogen is most likely a hydrogen at either end of the hydrocarbon chain. Isomers are possible, but uncommon.
   i. The hydrogens are replaced one at a time if multiple halogens are reacted.
   ii. The more reactive halogens (higher up on Table J) substitute for a hydrogen, therefore this is a substitution reaction.

   \[
   \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{H} + \text{F}_2 \quad \rightarrow \quad \text{F} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{H} \quad + \quad \text{HF} \\
   \text{ethane} \quad \text{fluorine gas} \quad \text{fluoro ethane} \quad \text{hydrofluoride gas}
   \]

   The fluorine replaces a hydrogen atom on the ethane molecule. The hydrogen that is removed bonds with the other fluorine atom to form a molecule of hydrogen fluoride. If this process is repeated, the other fluorine can replace another hydrogen.

Alkane Halogen Substitution Examples (Molecular Formulas):

- \( \text{C}_3\text{H}_8(g) + \text{Cl}_2(g) \rightarrow \text{C}_3\text{H}_7\text{Cl}_1(g) + \text{HCl}(g) \)  
  One Cl replaced one H

- \( \text{C}_4\text{H}_{10}(g) + \text{HBr}_1(g) \rightarrow \text{C}_4\text{H}_9\text{Br}_1(g) + \text{H}_2(g) \)  
  The Br replaced one H
Addition Reactions:

1. If an unsaturated hydrocarbon (alkene or alkyne) reacts with a halogen, the mechanism is that the multiple bonds (double = alkene, triple = alkyne) is broken, and the halogen atoms add to the new bonding sites.

![Diagram of alkene halogen addition]

**Alkene Halogen Addition Examples (Molecular Formulas):**

\[
\begin{align*}
C_3H_6(g) + Cl_2(g) & \rightarrow C_3H_6Cl_2(g) & \text{Both Cl atoms are added} \\
C_4H_8(g) + HBr(g) & \rightarrow C_4H_9Br(g) & \text{Both the H and Br are added}
\end{align*}
\]
Aromatic Hydrocarbons:

- A class of hydrocarbons that possess a **cyclical** shape and a special type of **bonding** known as **resonance** are the aromatic hydrocarbons.
- They are known as aromatic hydrocarbons as many of them have distinct smells that distinguish them.
  
i. Benzene (C$_6$H$_6$) is the most common base for aromatic compounds.

ii. Benzene has six carbon atoms arranged in a six-sided (hexagonal) ring. If you count the number of hydrogen atoms (six), with the six carbon atoms, every other alternating C-C bond should be a double (C=C) bond to satisfy the four bond sites that carbon contains. That doesn’t really happen in benzene. The **bonds** in an **aromatic** ring **oscillate** rapidly between single and double; the actual bond could be anything between. That is why a benzene ring is shown as a hexagon with a circle (solid or dashed) inside to show that the bonds are NOT fixed as single or double, but in some in-between state.

---

Watch Crash Course Chemistry Aromatic & Cyclic Compounds YouTube video - 9:49

https://www.youtube.com/watch?v=kXFEx-dABU
iii. For a hydrocarbon with double bonds (alkene), the addition of a halogen should cause a double bond to break, and the halogen add to the carbon at the new bonding sites.

\[
\begin{align*}
\text{H} & \quad \text{C} = \text{C} \quad \text{H} \quad + \quad \text{Br}_2 \quad \rightarrow \quad \text{H} & \quad \text{C} \quad \text{C} \quad \text{H} \\
\text{H} & \quad & \text{Br} & \quad \text{Br}
\end{align*}
\]

Ethylene  Bromine  (brownish-red)  1,2-Dibromoethane  (colorless)

iv. This doesn’t occur in the aromatic ring, giving evidence of that in-between bonding state as seen below.

\[\text{For halogens, two opposing effects}\]

\[
\begin{align*}
\text{Cl} & \quad \text{phenyl} \\
\text{negative inductive effect} & \text{positive mesomeric effect} \\
\text{withdrawing electron density from the benzene ring} & \text{donating electron density to the benzene ring}
\end{align*}
\]

Ch. 15 - 82
Regents Practice Problems-Additions & Substitutions (ungraded):

1. Base your answer to the following question on the organic reaction below.

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{O} \quad \text{H} \\
\text{H} & \quad \text{Br}_2 \\
\end{align*}
\rightarrow
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{C} \\
\text{H} & \quad \text{Br} \\
\end{align*}
\]

This reaction is an example of

a) Addition                     c) Fermentation
b) Substitution                 d) Saponification

2. What type of reaction is represented by the equation below?

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{H} \\
\end{align*}
\rightarrow
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \\
\text{H} & \quad \text{H} \\
\end{align*}
\]

a) Addition                     c) Fermentation
b) Substitution                 d) Esterification

3. As a substitution reaction occurs, the number of electrons shared between carbon atoms

a) Increases                     b) Decreases                     c) Remains the same

4. Given the equation: \( \text{CH}_4 + \text{Br}_2 \rightarrow \text{CH}_3\text{Br} + \text{HBr} \)

Which type of reaction does this equation represent?

a) An addition reaction           c) Saponification reaction
b) A substitution reaction        d) An esterification reaction

5. Which molecular formula could be represented by the structural formula shown below?

\[
\begin{align*}
\text{C}_6\text{H}_6 \\
\end{align*}
\]

a) \( \text{C}_6\text{H}_6 \)  b) \( \text{C}_6\text{H}_{10} \)  c) \( \text{C}_6\text{H}_{12} \)  d) \( \text{C}_6\text{H}_{14} \)
Notes page:
Substituted Hydrocarbons homework

Multiple choice & fill-in questions: circle the correct answer choice. 1 pt. ea.

1. Which of the following reactions is an addition reaction?
   a) $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$
   b) $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$
   c) $C_3H_8 + HBr \rightarrow C_3H_7Br + H_2$
   d) $CH_4 + 2 O_2 \rightarrow CO_2 + 2 H_2O$

2. Which of these hydrocarbons could undergo an addition reaction?
   a) CH$_4$  b) C$_3$H$_8$  c) C$_4$H$_8$  d) C$_5$H$_{12}$

3. Which of these hydrocarbons could form when propane reacts with Cl$_2$?
   a) C$_3$H$_8$Cl  b) C$_3$H$_6$Cl$_2$  c) C$_3$H$_7$Cl$_2$  d) C$_3$H$_8$Cl$_2$

Complete the following reactions and indicate whether they are addition or substitution reactions, and name the formed halocarbon.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Addition or Substitution?</th>
<th>Compound name</th>
</tr>
</thead>
</table>
| 4. $H \quad H$
  $\quad H - C - C - H + Br_2 \rightarrow$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Addition or Substitution?</th>
<th>Compound name</th>
</tr>
</thead>
</table>
| 5. $H \quad H$
  $\quad H - C - C = C - H + Br_2 \rightarrow$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Addition or Substitution?</th>
<th>Compound name</th>
</tr>
</thead>
</table>
| 6. $H \quad H$
  $\quad H - C - C - H + HBr \rightarrow$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Addition or Substitution?</th>
<th>Compound name</th>
</tr>
</thead>
</table>
| 7. $H \quad H$
  $\quad H - C - C = C - H + HBr \rightarrow$

Cont’d next page:
Name each of the following compounds: 1 pt. ea.

8. __________________________ 9. __________________________

10. __________________________ 11. __________________________

Draw the structural formulas for the following compounds: 1 pt. ea.

12. 2-chloropropane

13. 3-methylheptane

14. 1,2-dichlorobutane

15. 2,2-dimethyloctane
Topic: **Functional Groups & Families**

Objective: How do we group certain atoms according to function?

**Functional Groups:**

- A functional group is a certain combination of atoms in a distinct structure in a particular position on a molecule that provides very special properties to the molecule as a whole.

<table>
<thead>
<tr>
<th>Class of Compound</th>
<th>Functional Group</th>
<th>General Formula</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>halide (halocarbon)</td>
<td>(-F) (fluoro-)</td>
<td>(R-X) ((X) represents any halogen)</td>
<td>(CH_3CH_2CH_3) 2-chloropropene</td>
</tr>
<tr>
<td>alcohol</td>
<td>(-OH)</td>
<td>(R-OH)</td>
<td>(CH_3CH_2CH_2OH) 1-propanol</td>
</tr>
<tr>
<td>ether</td>
<td>(-O-)</td>
<td>(R-O-R')</td>
<td>(CH_3OCH_2CH_3) methyl ethyl ether</td>
</tr>
<tr>
<td>aldehyde</td>
<td>(\overset{\circ}{O} - \overset{\circ}{C} - \overset{\circ}{H})</td>
<td>(R-C-H)</td>
<td>(CH_3CH_2C=H) propanal</td>
</tr>
<tr>
<td>ketone</td>
<td>(\overset{\circ}{O} - \overset{\circ}{C} - \overset{\circ}{C})</td>
<td>(R-C-R')</td>
<td>(CH_3CH_2CH_2CH_3) 2-pentanone</td>
</tr>
<tr>
<td>organic acid</td>
<td>(\overset{\circ}{O} - \overset{\circ}{C} - OH)</td>
<td>(R-C-OH)</td>
<td>(CH_3CH_2C=OH) propanoic acid</td>
</tr>
<tr>
<td>ester</td>
<td>(\overset{\circ}{O} - \overset{\circ}{O} - \overset{\circ}{O})</td>
<td>(R-C-O-R')</td>
<td>(CH_3CH_2COCH_3) methyl propanoate</td>
</tr>
<tr>
<td>amine</td>
<td>(-N-)</td>
<td>(R'-N-R'')</td>
<td>(CH_3CH_2CH_2NH_2) 1-propanamine</td>
</tr>
<tr>
<td>amide</td>
<td>(-C-NH)</td>
<td>(R'-C-NH)</td>
<td>(CH_3CH_2C=NH_2) propanamide</td>
</tr>
</tbody>
</table>

*Note: \(R\) represents a bonded atom or group of atoms.*
Alcohols:

1. **Alcohols** are a group of saturated (no double bond) hydrocarbons that have at least one substituted **hydroxyl** (–OH) functional group.
2. The hydroxyl (-OH) group is more electronegative and makes the **alcohol** molecule **polar**.
3. Smaller (low number of carbon) alcohols are soluble in water.
4. The hydroxyl (-OH) group is covalently bonded in alcohol, and does not dissociate in water. Alcohols are **not** bases.
5. Alcohols are **named** like any other hydrocarbon. The suffix becomes “-ol”, and the position of the (-OH) group is indicated by the lowest-numbered carbon.
Types of alcohols:

Monohydroxy-containing one hydroxyl (-OH) group

- Methanol (wood alcohol, methyl alcohol): a one-carbon alcohol. Methanol is the most polar alcohol, and is then the most soluble in water. Methyl alcohol is very poisonous to humans.

- Ethanol (grain alcohol, ethyl alcohol): a two-carbon alcohol. Easily soluble (is polar) in water, a poisonous waste product of fermentation.

- 2-propanol (isopropyl alcohol, rubbing alcohol): a three-carbon alcohol with the –OH group bonded to the middle (2\textsuperscript{nd}) carbon atom. Most households have 2-propanol in their bathroom cabinets.

Dihydroxy – containing two hydroxyl (-OH) groups

- 1,2-ethanediol (ethylene glycol): a two-carbon dihydroxy alcohol derived from ethene with hydroxyl groups on both the 1\textsuperscript{st} and 2\textsuperscript{nd} carbon atoms. A non-electrolyte that is the basis of antifreeze; is a deadly poison, yet has a temptingly sweet taste.

Trihydroxy – containing three hydroxyl (-OH) groups

- 1,2,3-propanetriol (glycerol, glycerin): a three-carbon trihydroxy alcohol with hydroxyl groups on each carbon. Glycerol is nontoxic, and found as a food and medicine preservative, and a laboratory lubricant for glassware.
Positioning of the Hydroxyl Functional Group:

If the functional group is on a carbon bonded to no other carbons or only one other carbon, then it is a primary alcohol.

Primary Alcohol: The hydroxyl group is bonded to an end carbon. The end carbon is a PRIMARY carbon as it is bonded to only one other carbon atom.

If the functional group is on a carbon that is bonded to two other carbons, then it is a secondary alcohol.

Secondary Alcohol: The hydroxyl group is bonded to the middle carbon. The center carbon is a SECONDARY carbon as it is bonded to two other carbon atoms.

If the functional group is bonded to a carbon that is bonded to three other carbons, then it is a tertiary alcohol.

Tertiary Alcohol: The hydroxyl group is bonded to a non-end carbon with a methyl (-CH₃) group bonded to the same carbon as the –OH. This non-end carbon is directly bonded to three other carbons, making it a TERTIARY carbon.

Watch Crash Course Chemistry Hydrocarbon Derivatives YouTube video - 8:38
https://www.youtube.com/watch?v=U7wavimfNFE
Regents Practice Problems-Alcohols (ungraded):

1. Which type of organic compound is represented by the structural formula shown below?

   ![Structural formula](image)

   a) Ether  
   b) Ester  
   c) Alcohol  
   d) Aldehyde

2. Which compound is an alcohol?

   a) Butane  
   b) Ethyne  
   c) Propanal  
   d) Methanol

3. Which organic compound is most soluble in water?

   a) Butane  
   b) Ethyne  
   c) Ethanol  
   d) Benzene

4. If a compound contains only one functional -OH group attached to the end carbon of a chain, the compound is classified as a

   a) Tertiary alcohol  
   b) Primary alcohol  
   c) Secondary alcohol  
   d) Dihydroxy alcohol

5. To be classified as a tertiary alcohol, the functional -OH group is bonded to a carbon that must be bonded to a total of how many additional carbon atoms?

   a) 1  
   b) 2  
   c) 3  
   d) 4
Organic Acids:

- **Organic Acids** belong to a group of hydrocarbons that contain the functional **carboxyl** group –COOH. While one of the oxygen atoms and the hydrogen together may make it look like an alcohol, it is not.

<table>
<thead>
<tr>
<th>Organic Acid functional group –COOH (Carboxyl group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The “R” is the attached hydrocarbon chain</td>
</tr>
<tr>
<td>The hydrogen on attached to the oxygen dissociates in water, allowing the acidic properties</td>
</tr>
<tr>
<td>The shorter the “R” chain, the stronger the organic acid</td>
</tr>
<tr>
<td>Carboxyl (-COOH) are attached to a primary carbon only</td>
</tr>
<tr>
<td>Parent name of hydrocarbon with “-oic acid” added</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methanoic Acid (formic acid): a one-carbon organic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible for the pain in fire ant bites.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethanoic Acid (acetic acid): a two-carbon organic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>White vinegar is a 5% aqueous solution of acetic acid</td>
</tr>
</tbody>
</table>

**Topic:** Organic Acids

**Objective:** How will adding a carboxyl group change a hydrocarbon?
### Topic: Aldehydes & Ethers

**Objective:** Will adding a carbonyl or oxygen change a hydrocarbon?

### Aldehydes:

- **Aldehyde:** A hydrocarbon with a –CO (carbonyl) group plus hydrogen (–CHO) bonded to a primary chain carbon.

  ![Aldehyde Functional Group](image)

  - Aldehyde functional group R-CHO (Carbonyl Group)
  - The “R” is the attached hydrocarbon chain
  - Parent name of hydrocarbon with suffix “-al” added
  - Carbonyl Group positioned on primary carbon

  ![Methanal (Formaldehyde)](image)

  - Methanal (formaldehyde): a one-carbon aldehyde, used for biological specimen preservation
  - Also used in wood construction materials as a preservative/adhesive

  ![Ethanal](image)

  - Ethanal, a two-carbon aldehyde

### Ethers:

- **Ether:** A molecule of two hydrocarbon chains connected by a single oxygen molecule (–O–) between the two chains.

  ![Ether Functional Group](image)

  - Ether functional group R-O-R’
  - “R” and “R’” are parent and secondary hydrocarbon chain

  ![Methyl Ethyl Ether](image)

  - Name of shorter “R” chain is first; name of longer “R” chain is 2nd, followed by “ether”
  - Methyl Ethyl ether
Topic: **Ketones & Esters**

Objective: Will adding a 2nd functional group change a hydrocarbon?

**Ketones:**

- **Ketone**: A hydrocarbon with a –CO (carbonyl) group bonded onto a secondary carbon atom.

<table>
<thead>
<tr>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>R−C−R'</td>
</tr>
</tbody>
</table>

Carbonyl functional group R’-CO-R (Secondary Carbonyl)
Alternate (secondary) form of aldehyde
R’ and R are both hydrocarbon chains (at least methyl)
Parent name suffix is “-one”; positioning of carbonyl group on lowest numbered carbon

![Propanone (acetone): a three-carbon ketone, used in nail polish and nail polish remover](image)

**Esters:**

- **Ester**: A hydrocarbon with a –COO (carboxyl) group bonded to a secondary carbon atom.

<table>
<thead>
<tr>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>R−C−O−R'</td>
</tr>
</tbody>
</table>

R’-COO-R with carboxyl (-COO) functional group attached to two alkyl chains
Responsible for many scents, fragrances
BIG $$$ industry in perfumes, foods, etc.

<table>
<thead>
<tr>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
</tr>
<tr>
<td>H−C−C−O−C−C−C−C−C−H</td>
</tr>
</tbody>
</table>

Pentyl ethanoate (banana oil)
Produced by over-ripe bananas
Parent name suffix is “-ate” for chain with (−COO) bonded
Because families might share functional groups, those that do are isomers of each other.

i. Alcohols and ethers both have one oxygen atom.

ii. Organic acids and esters both share carboxyl (COO) groups.

iii. Aldehydes and ketones both share carbonyl (C=O) groups.

The only difference between the families that share functional groups is the positioning of the functional group. In ALL isomers, the molecular formula is the same; only the structural formula (shape) differs.

<table>
<thead>
<tr>
<th>Functional Families</th>
<th>Compound Example</th>
<th>Isomer Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohols &amp; Ethers</td>
<td>2-propanol (C₃H₈O)</td>
<td>Methyl ethyl ether (C₃H₈O)</td>
</tr>
<tr>
<td></td>
<td><img src="image1" alt="Structure" /></td>
<td><img src="image2" alt="Structure" /></td>
</tr>
<tr>
<td>Organic Acids &amp; Esters</td>
<td>Hexanoic acid (C₆H₁₂O₂)</td>
<td>Butyl ethanoate (C₅H₁₂O₂)</td>
</tr>
<tr>
<td></td>
<td><img src="image3" alt="Structure" /></td>
<td><img src="image4" alt="Structure" /></td>
</tr>
<tr>
<td>Aldehydes &amp; Ketones</td>
<td>Pentanal (C₅H₁₀O)</td>
<td>3-pentanone (C₅H₁₀O)</td>
</tr>
<tr>
<td></td>
<td><img src="image5" alt="Structure" /></td>
<td><img src="image6" alt="Structure" /></td>
</tr>
</tbody>
</table>
You need to be able to do these three things to for the Regents:

1. **Be able to recognize** what family a particular molecule containing a functional group belongs to. There are examples given on Reference Table R.

2. **Be able to name** simple examples of each kind of hydrocarbon family. Reference Table Q has the three basic hydrocarbons, and Reference Table P has the most common Organic Prefixes used.

3. **Be able to draw isomers** of various groups (alcohols are isomers of ethers, organic acids are isomers of esters, and ketones are isomers of aldehydes).

Watch Crash Course Chemistry Organic Nomenclature YouTube video - 9:04
https://www.youtube.com/watch?v=U7wavimfNFE
Regents Practice Problems-Other Functional Groups (ungraded):

1. What is the name of the compound with following formula?

   ![Chemical structure]

   a) Propanal        c) Propanone
   b) Propanol        d) Propanoic acid

2. Which organic compounds are often used to create fragrances for the perfume industry?
   a) esters          b) ethers          c) alkanes         d) alkynes

3. Which functional group, when attached to a chain of carbon atoms, will produce an organic molecule with the characteristic properties of an aldehyde?

   ![Functional groups]

   a) \(-\text{C}-\text{OH}\)          b) \(-\text{C}-\text{H}\)
   c) \(-\text{C}\)                    d) \(-\text{OH}\)

4. The functional group \(-\text{COOH}\) is found in
   a) esters          c) aldehydes
   b) alcohols        d) organic acids

5. Which of the following could be an isomer of the molecule below?

   ![Molecule structure]

   a)        b)        c)        d)
Functional Groups and Families homework

Complete the following table, identifying the functional group family and name.

<table>
<thead>
<tr>
<th>No.</th>
<th>Structure</th>
<th>Identify family</th>
<th>Compound name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>H H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>H H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>H H H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>H H H</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cont’d next page:
**Draw** the structures of the given organic compounds, identify the functional group family, and indicate if the functional group is attached to a primary or a secondary carbon.

<table>
<thead>
<tr>
<th>Compound name:</th>
<th>Functional family:</th>
<th>Structural formula:</th>
<th>Primary or Secondary carbon?</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. 2-pentanone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Propanoic acid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Methyl ethanoate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Methyl propyl ether</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. 2-pentanol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. 1-pentanol (n-pentanol)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Topic: **Dehydration Synthesis**

Objective: How do complex organic molecules form?

Dehydration Synthesis:

You learned in Living Environment that larger molecules are created (synthesized) by removing **hydrogen** (H) from one molecule and a **hydroxyl** (OH) group from the other molecule, then joining the broken bonds. The H and OH combine to form water (H₂O), or dehydrate.

**Etherification:**

i. Requires two reactant alcohols;

ii. H₂SO₄ is the dehydrating agent.

\[
\begin{align*}
\text{H} & \quad \text{C} & \quad \text{O} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\quad \text{H}_2\text{SO}_4 \quad \begin{align*}
\text{H} & \quad \text{C} & \quad \text{O} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\quad \begin{align*}
\text{H} & \quad \text{C} & \quad \text{O} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H}
\end{align*}
\quad \text{H}_2\text{O}
\]

\[\text{Methanol} + \text{Ethanol} \quad \rightarrow \quad \text{methyl ethyl ether} + \text{water}\]

The sulfuric acid removes H from methanol and OH from ethanol (dehydration) to form water. The two alcohols join together at the dehydration sites forming ether.
Esterification:

i. Requires an alcohol and a carboxylic acid;

ii. Forms an ester, named for the alcohol and acid that formed it.

\[
\begin{align*}
\text{Ethanoic acid} + 1\text{-butanol} & \rightarrow \text{butyl ethanoate} + \text{water} \\
\text{H}_2\text{C} &= \text{C} - \text{OH} + \text{HO} - \text{C} &= \text{C} - \text{C} &= \text{C} &= \text{C} &= \text{H} &\xrightarrow{\text{H}_2\text{SO}_4} \text{H} &= \text{C} &= \text{C} &= \text{O} &= \text{C} &= \text{C} &= \text{C} &= \text{C} &= \text{H} + \text{H}_2\text{O}
\end{align*}
\]

The sulfuric acid removes H from the acid and OH from the alcohol (dehydration) to form water. The acid and alcohol join at the removal sites, forming butyl (\textit{but}- from \textit{butanol}) ethanoate (\textit{ethano}- from \textit{ethanoic} acid).
Fermentation:

- Fermentation of glucose or fructose, found in corn, barley, grapes, apples, etc., forms ethanol (ethyl alcohol) when in the presence of yeast (zymase) and the absence of oxygen (anaerobic).

\[ C_6H_{12}O_6 \rightarrow 2 \text{CH}_3\text{CH}_2\text{OH} + 2 \text{CO}_2 \]

- The reaction proceeds until the alcohol content reaches about 13% by volume, when the yeast dies of alcohol toxicity.

Saponification:

- Saponification is the production of soap, a combination of polar and nonpolar molecules.
  
  i. Saponification requires a glycerol ester (fat) and a strong base (NaOH).
  
  ii. The glycerol ester is dissolved in ethanol, and the base is combined;
  
  iii. The mixture is heated slowly until it thickens;
  
  iv. The alcohol solvent is evaporated (vaporized) off;
  
  v. The resulting mixture is glycerol plus the salts of the long-chain acids;
  
  vi. The sodium stearate salts may be precipitated by adding NaCl, then filtering out the glycerol, leaving the soap product.
Saponification process:

\[ C_{17}H_{35}COO)^3C_3H_5 + 3 \text{NaOH} \rightarrow C_3H_5(OH)^3 + C_{17}H_{35}COONa \]
Topic: **Polymerization**

Objective: How do complex organic molecules form from monomers?

Polymerization:

- A polymer is a very large molecule made by connecting many smaller molecules (monomers) together. Starches are one example of natural polymers; many synthetic polymers have been made in laboratories and polymers are BIG business in industry.

- A monomer molecule may be represented by the letter ‘A’:


  i. The polymer 18 A may be abbreviated as: \((-\text{A})_{18}\), representing a chain of ‘A” monomers totaling 18 monomers in length.
Types of Polymers:

Addition Polymers:

- Addition polymers are formed by an addition polymerization reaction.
  
  i. The monomer’s double bond opens, allowing the monomer units to join end to end.
  
  ii. The name of the polymer is found by putting a “poly” in front of the monomer unit name.

  Ex: many propylene monomers form polypropylene

Addition polymer examples:

1. Polyvinyl chloride:
   
   i. Formed from multiple Vinyl Chloride (VC) monomers (chlorethene);
   
   ii. Double bond is broken, and VC monomer units join end-to-end;
   
   iii. Used in pipes, rain wear, shower curtains, vinyl siding, insulation

   ![Polyvinyl Chloride Structure]

   1) Vinyl chloride monomers, separate from each other

   ![Polyvinyl Chloride Structure with Catalyst]

   2) A catalyst breaks the double bonds, opening up a free unpaired valence electron on each C

   ![Polyvinyl Chloride Structure with Ends]

   3) The vinyl chloride monomers join end to end. The reaction is terminated by the addition of hydrogen gas, which adds on to the end of the polyvinyl chloride molecule, stopping any further polymerization.
2. Polystyrene:
   i. Formed from multiple styrene monomers (phenylethene);
   ii. Double bond is broken, and styrene monomer units join end-to-end;
   iii. Used in plastic model kits, Styrofoam (low density)

\[
\begin{align*}
\text{n number of styrene monomer units combine together to form a chain of styrene monomers n units long. If you start with 2000 styrene monomer units, the polymer will be 2000 units long.}
\end{align*}
\]

3. Polytetrafluoroethene (Teflon):
   i. Formed from multiple tetrafluoroethene (TFE) monomers;
   ii. Double bond is broken, and TFE monomer units join end-to-end;
   iii. Non-stick pan coating; accidental discovery in 1938

\[
\begin{align*}
\text{n number of TFE monomer units combine together to form a chain of TFE monomer n units long. If you start with 1500 TFE monomer units, the polymer will be 1500 units long.}
\end{align*}
\]
Condensation Polymers:

- Condensation polymers are formed by **dehydration** synthesis of difunctional (two different functional groups) monomer units.
  
  i. H and OH are removed from the **ends** of the monomer units, allowing them to be joined together.
  
  ii. Water is the (dehydration) byproduct.

1. Polyester:
  
  i. Formed from a primary alcohol monomer and a primary carboxylic acid monomer;
  
  ii. The opposing functional ends undergo dehydration synthesis, forming the polymer and water

\[
\begin{align*}
\text{HO-C-C-OH} + \text{HO-C-C-OH} + \text{HO-C-C-OH} + \text{HO-C-C-OH} + \text{HO-C-C-OH} + \text{HO-C-C-OH} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{align*}
\]

The monomers above lose H and OH and bond together through dehydration synthesis to form polyester. \( n-1 \) water is lost, because only the H's and OH's between the monomer units are lost.

\[
\begin{align*}
\text{HO-C-C-O-C-C-O-C-C-O-C-C-O-C-C-O-C-C-OH} + 4 \text{H}_2\text{O} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{align*}
\]

\[
\begin{align*}
\text{H} \quad \text{O} \\
\text{H} \quad \text{O}
\end{align*}
\]

\[
\begin{align*}
\text{HO-C-C-OH} \rightarrow \quad \text{HO-C-C-OH} + \text{H} + \text{H}_2\text{O} \\
n \quad \text{H}_2\text{O} \quad \text{n-1} \quad \text{H}_2\text{O}
\end{align*}
\]

**Watch Crash Course Chemistry Polymers YouTube video** - 10:14

https://www.youtube.com/watch?v=rHxxLYzJ8Sw
Combustion:

- Combustion Reactions are a special type of reaction (Unit 8) where a **hydrocarbon** combines with **oxygen** in the presence of heat to **form carbon dioxide** and **water** as the ONLY products.
- This is known as complete combustion, and only occurs in the presence of pure oxygen.

\[
\begin{align*}
(a) \quad & \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g) + \text{energy} \\
(b) \quad & \text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(g) + \text{energy} \\
(c) \quad & 2\text{C}_6\text{H}_{14}(l) + 19\text{O}_2(g) \rightarrow 12\text{CO}_2(g) + 14\text{H}_2\text{O}(g) + \text{energy} \\
(d) \quad & 2\text{C}_8\text{H}_{18}(l) + 25\text{O}_2(g) \rightarrow 16\text{CO}_2(g) + 18\text{H}_2\text{O}(g) + \text{energy}
\end{align*}
\]

- Note that the initial activation energy is NOT shown in these exothermic reactions.
Topic: **Identifying Organic Reactions**

Objective: What do **you** need to be able to do for organic Rx’s?

What do you need to be able to do for identifying Organic Reactions?

1. Recognize the type of reaction when you see it:

<table>
<thead>
<tr>
<th>Reaction formula:</th>
<th>Reaction type:</th>
<th>How do you know?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ + 2 O₂ → CO₂ + 2 H₂O</td>
<td>Combustion</td>
<td>A hydrocarbon reacts with oxygen, forming CO₂ &amp; H₂O</td>
</tr>
<tr>
<td>C₃H₈ + Cl₂ → C₃H₇Cl + HCl</td>
<td>Substitution</td>
<td>A Cl replaces one of the H in the hydrocarbon</td>
</tr>
<tr>
<td>C₆H₁₂O₆ → 2 CO₂ + 2 C₂H₅OH</td>
<td>Fermentation</td>
<td>Sugar forms ethanol</td>
</tr>
<tr>
<td>C₃H₆ + Cl₂ → C₃H₆Cl₂</td>
<td>Addition</td>
<td>No H atoms removed; Cl added to propene (lost the C=C)</td>
</tr>
<tr>
<td>CH₃COOH + CH₃OH → CH₃COOCH₃ + H₂O</td>
<td>Esterification</td>
<td>An ester is formed (COO in middle of two chains)</td>
</tr>
<tr>
<td>CH₃OH + CH₃CH₂OH → CH₃OCH₂CH₃ + H₂O</td>
<td>Etherification</td>
<td>An ether is formed (O in the middle of two chains)</td>
</tr>
<tr>
<td>5000 C₂H₄ → -(C₂H₄-)-5000</td>
<td>Polymerization</td>
<td>A large, many monomer polymer is formed</td>
</tr>
</tbody>
</table>

2. Determine the reactants needed to make a particular product:

<table>
<thead>
<tr>
<th>Desired product:</th>
<th>Reaction to form product:</th>
<th>Reactants needed to form product:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>Fermentation</td>
<td>Sugar (glucose or fructose); yeast</td>
</tr>
<tr>
<td>1,5 difluoropentane</td>
<td>Substitution (F’s substitute for H’s at ends of pentane molecule)</td>
<td>Pentane and diatomic fluorine (F₂)</td>
</tr>
<tr>
<td>2,3 difluoropentane</td>
<td>Addition (adds F’s next to each other in molecule)</td>
<td>2-pentene(C=C bond between 2nd &amp; 3rd carbons break) and F₂</td>
</tr>
<tr>
<td>Ethyl propanate</td>
<td>Esterification</td>
<td>Ethanol and propanoic acid</td>
</tr>
<tr>
<td>Methyl propyl ether</td>
<td>Etherification</td>
<td>Methanol and propanol</td>
</tr>
<tr>
<td>Polyisoprene</td>
<td>Polymerization</td>
<td>Many isoprene monomers</td>
</tr>
</tbody>
</table>
Regents Practice Problems—Organic Reactions (ungraded):

1. The principal products of saponification, a reaction between a fat and a base, are soap and
   a) Water       c) Ethyl alcohol
   b) Glycerol   d) Carbon dioxide

2. The fermentation of C\(_6\)H\(_{12}\)O\(_6\) will produce CO\(_2\) and
   a) Ca(OH)\(_2\)  c) C\(_2\)H\(_5\)OH
   b) Cr(OH)\(_3\)  d) C\(_3\)H\(_5\)(OH)\(_3\)

3. The process of joining many small molecules into larger molecules is called
   a) Substitution  c) Saponification
   b) Neutralization d) Polymerization

4. Which organic reaction produces rubber and plastics?
   a) Fermentation  c) Saponification
   b) Esterification d) Polymerization

5. The reaction of \(nC_2H_4 \rightarrow (-C_2H_4^-)_n\) is an example of
   a) Fermentation  c) Saponification
   b) Esterification d) Polymerization
Organic Reactions homework

Identify the type of reaction shown. 1 pt. ea.

1. The reaction that occurs when a hydrocarbon is heated in the presence of oxygen is
   a) Combustion         c) Vulcanization
   b) Fermentation       d) Saponification

2. The reaction used to manufacture soap products is
   a) Combustion         c) Vulcanization
   b) Fermentation       d) Saponification

Multiple choice questions: circle the correct answer choice. 1 pt. ea.

Cont’d next page:
3. The reaction that produces ethanol by the digestion of sugars by yeast is
   a) Combustion       c) Vulcanization
   b) Fermentation     d) Saponification

4. Which reaction may be used to make 2, 3-dichloropentane?
   a) Addition     c) Esterification
   b) Substitution d) Etherification

5. Which reaction may be used to make propylethanoate?
   a) Addition     c) Esterification
   b) Substitution d) Etherification

Identify the type of reaction shown below by writing the type of reaction in the
specified location. Each reaction type (as on pg. 60) is used only once. 1 pt. ea.

<table>
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<tr>
<th>Reaction formula</th>
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<tbody>
<tr>
<td>C₂H₄ + Cl₂ → C₂H₄Cl₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₃OH + CH₃COOH → CH₃COOCH₃ + H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₄ + 2 O₂ → CO₂ + 2 H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₆H₁₂O₆ → 2 C₂H₅OH + 2 CO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₃H₈ + HBr → C₃H₇Br + H₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₃OH + CH₃OH → CH₃OCH₃ + H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200 C₂H₄ → -(-C₂H₄-)_1200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>