

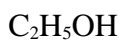
# Organic Nomenclature and Simple Reactions

Organic chemistry involves the chemistry of compounds containing carbon. Because of carbon's unique ability to bond with itself in a large variety of ways, the field of organic chemistry involves over six million compounds. Not only are organic compounds a vital constituent of all living things but they also contribute to the wide variety of materials we use in our modern lifestyles. Plastics we recycle, gasoline that we burn, and synthetic materials that we wear are all organic. In addition to carbon, organic compounds contain other elements as well, most commonly hydrogen, oxygen, nitrogen, sulfur, phosphorus, and the halogens.

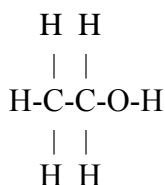
The properties of organic compounds differ from those of inorganic compounds most notably their relatively low melting points (generally under 300°C), low boiling points, solubility in other organic solvents rather than water, and poor electrical conductivity. Organic reactions often have slow reaction rates and provide low yields of product due to the tendency for many side reactions to occur.

References to organic compounds may be made either by name or by formula. Because of the variation in structures, three different types of formulas are commonly used. The definition and an example of each type of formula are given below, using ethanol (ethyl alcohol) as the example compound.

*Molecular formulas* indicate the type and number of each atom in the compound yet give no information about the bonds or the structure of the compound.



*Structural formulas* indicate the complete two-dimensional structures of the compound, showing all of the bonds present.



*Condensed structural formulas* are shorthand representations that leave the bond lines out, yet still indicate what is bonded to each carbon or other atom.



## **Hydrocarbons**

A large number of organic compounds fall into a category known as hydrocarbons. As the name implies, these compounds consist of only carbon and hydrogen but even those two elements can produce a wide variety of compounds. Hydrocarbons can also be subdivided into two groups- open or acyclic hydrocarbons, and closed or cyclic (ring) hydrocarbon.

The acyclic hydrocarbons consist of chains of carbon atoms with hydrogen attached to the outside of the chain. Since the chain of carbon can be covalently bonded with either single, double, or triple pairs of shared electrons, three groups of acyclic hydrocarbons emerge-alkanes, alkenes, and alkynes.

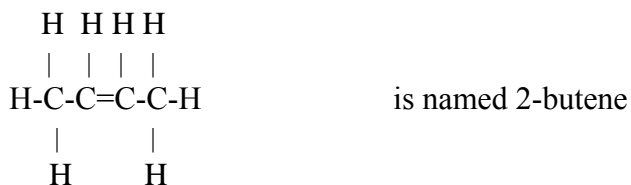
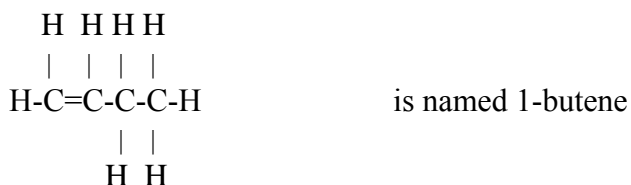
*Alkanes* are hydrocarbons in which there are only single covalent bonds between the carbon atoms. The general formula for alkanes is  $\text{C}_n\text{H}_{2n+2}$ , where n is the number of carbon atoms in the chain. Because carbon exhibits only single bonds and it has four effective electron pairs, it displays  $\text{sp}^3$  hybridization in all alkanes. The length

of the carbon chain tends to affect physical properties such as boiling point and melting point due to the variation in strength of the dispersion forces. Naming alkanes is straightforward—simply use the prefix stem listed in the box below to indicate the number of carbons in the chain and add the suffix *-ane* to the end. Thus an alkane containing six carbons is named hexane, while one containing three carbons is named propane.

### Prefix Stems for Organic Compound Names

1 meth-	5 pent-	9 non-
2 eth-	6 hex-	10 dec-
3 prop-	7 hept-	
4 but-	8 oct-	

*Alkenes* are hydrocarbons in which there is at least one double covalent bond between the carbon atoms. The general formula for alkenes is  $C_nH_{2n}$ , where  $n$  is the number of carbon atoms in the chain. Because carbon exhibits one double bond and two single bonds, it has three effective electron pairs and displays  $sp^2$  hybridization. To name alkenes, indicate where the double bond occurs and numbering the carbon chain starting with the end closest to the double bond. Then use the prefix stem to indicate the number of carbons in the chain and add the suffix *-ene* to the end. For example,



For chains that contain two double bonds, list the location of the two double bonds and use the suffix *-diene* at the end. Draw the structural formula for 1,3-butadiene.

*Alkynes* are hydrocarbons in which there is at least one triple covalent bond between the carbon atoms. The general formula for alkynes is  $C_nH_{2n-2}$ , where  $n$  is the number of carbon atoms in the chain. Because carbon exhibits one triple bond and one single bond in alkynes, it has two effective electron pairs and displays  $sp$  hybridization. To name alkynes, indicate where the triple bond occurs by numbering the carbon chains starting with the end closest to the triple bond. Then use the prefix stem to indicate the number of carbons in the chain and add the suffix *-yne* to the end.

The most common cyclic organic compounds are the ones that are derivatives of benzene,  $C_6H_6$ . This six-member carbon ring has three alternating double bonds and can be found with many different components attached to it including other benzene rings. Other cyclic hydrocarbons include cyclobutane and cyclopentane.

### Naming Branched Hydrocarbons

Thus far, the naming of different types of straight chain hydrocarbons have been considered. Hydrocarbons can also be formed by attaching hydrocarbon groups onto a hydrocarbon chain. These are generally referred to as branched hydrocarbons. General rules for naming these compounds are as follows:

- For *alkanes*, locate the longest continuous chain of carbon atoms and count the number of atoms-this chain determines the prefix stem name for the compound. For *alkenes and alkynes*, locate the carbon atoms in the longest carbon chain that contains the double or triple bond-this will give the prefix stem name for the compound.
- Look for any groups other than hydrogen that may appear in the molecule. These are called substituent groups. There will be a special prefix for each such substituent group. For example:

Subsistent group		Prefix
-CH <sub>3</sub>	1-carbon group	methyl
-CH <sub>2</sub> CH <sub>3</sub>	2-carbon group	ethyl
-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	3-carbon group	propyl
-Cl	chlorine atom	chloro
-Br	bromine atom	bromo

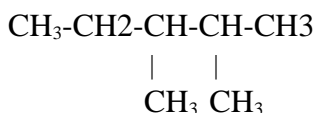
*Note: Take the time to memorize the first 10 prefixes-it will help in naming thousands of compounds.*

- If more than one substituent group of any kind is present, use Greek prefixes to indicate the number. For example, use:
 

di-	for 2
tri-	for 3
tetra-	for 4
- Number the longest continuous carbon chain beginning with the end of the chain nearest the substituent. Use the numbers to designate the location of the substituent group(s). If there are more than two substituent groups of the same kind, give each group a number.
- For *alkanes*, always count from the end of the chain that will give the lowest possible combination of numbers. In other words, start counting from the end closest to the substituent group. For *alkenes and alkynes*, always count from the end of the chain that the double or triple bond is closer to; disregard the branch chain rule used for alkanes.
- Use hyphens to separate numbers from names and commas to separate numbers from each other. Substituent groups should be listed alphabetically, disregarding the Greek prefixes.

**Example 1:** CH<sub>3</sub>CH<sub>2</sub>CH(CH<sub>3</sub>)CH(CH<sub>3</sub>)CH<sub>3</sub>

*Condensed Formula*

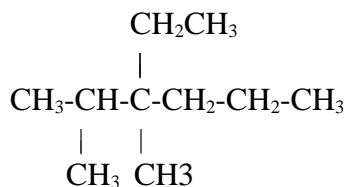


*Structural Formula*

Name: 2,3-dimethylpentane

**Example 2:** CH<sub>3</sub>CH(CH<sub>3</sub>)C(CH<sub>3</sub>)(CH<sub>2</sub>CH<sub>3</sub>)CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>

*Condensed Formula*



*Structural Formula*

Name: 3-ethyl-2,3-dimethylhexane

## Other Organic Functional Groups

Many remaining organic compounds can be divided into groups based on their unique structure. They include variations with oxygen and nitrogen and the means which they bond to carbon and hydrogen. Each group has recognizable structural characteristics and names which are an extension of the general hydrocarbon naming rules.

*Note:* R = a general symbol to represent any carbon chain; and  
Systematic name = the official IUPAC name of the compound.

### A. Alcohols R-OH

1. Can be oxidized to aldehydes, carboxylic acids or ketones.
2. Systematic name:
  1. Can be oxidized to aldehydes, carboxylic acids or ketones.
  2. Systematic name:
    - indicate the number of the carbon to which the -OH group is attached
    - drop the "e" from the name of the corresponding alkane and add the suffix *-ol*

### B. Ethers R-O-R'

1. Relatively unreactive compounds
2. Systematic name:
  - use the root for R, add the suffix *-oxy* followed by the corresponding alkane for R'

### C. Carboxylic Acids R-COOH

1. Formed from the oxidation of primary alcohols (-OH on the end carbon)
2. Tend to be polar and to form hydrogen bonds
3. Systematic name:
  - drop the "e" from the name of the corresponding alkane and add the suffix *-oic* followed by the word *acid*.

### D. Esters R-COO-R'

1. Derived from an acid and an alcohol
2. Low molecular mass esters tend to have fruity odors
3. Systematic name:
  - name the alcohol part of the compound (the group to the right of the COO) with its *-yl* ending
  - name the acid part of the compound (the group to the left of the COO and including the carbon in COO) with an *-oate* ending.

### E. Aldehydes R-CHO

1. Derived from the oxidation of a primary alcohol
2. Can be oxidized to a carboxylic acid
3. Systematic name:
  - take the parent name, drop the "e" and add the suffix *-al*

### F. Ketones

1. Derived from the oxidation of a secondary alcohol
2. Systemic name:
  - Consider the total number of carbons, take the parent alkane name, drop the "e" and add the suffix *-one*

G. Amines  $R-NH_2$

1. Are weakly basic compounds (may be considered to be derivatives of ammonia)
2. Tend to have offensive odors (think of decaying fish)
3. Systematic name:
  - name the R group and add the word *amine*

H. Amides  $R-CO-NH_2$

1. Derived from a carboxylic acid and an amine
2. Significant in synthetic polymers and proteins
3. Systematic name:
  - consider the total number of carbons-take the parent alkane name, drop the "e", add the suffix *-yl*, and add the word *amide*.

**Organic Functional Groups**

Category	Functional Group	General Formula	Example
Alcohols	-OH	R-OH	CH <sub>3</sub> OH methanol
Ethers	-O-	R-O-R'	CH <sub>3</sub> OCH <sub>3</sub> methoxymethane
Carboxylic acids	$\begin{array}{c} O \\    \\ -C-O-H \end{array}$	$\begin{array}{c} O \\    \\ R-C-O-H \end{array}$	CH <sub>3</sub> COOH ethanoic acid
Esters	$\begin{array}{c} O \\    \\ -C-O- \end{array}$	$\begin{array}{c} O \\    \\ R-C-O-R' \end{array}$	CH <sub>3</sub> COOCH <sub>3</sub> methylethanoate
Aldehydes	$\begin{array}{c} O \\    \\ -C-H \end{array}$	$\begin{array}{c} O \\    \\ R-C-H \end{array}$	CH <sub>3</sub> CHO ethanal
Ketones	$\begin{array}{c} O \\    \\ -C- \end{array}$	$\begin{array}{c} O \\    \\ R-C-R' \end{array}$	CH <sub>3</sub> CH <sub>2</sub> COCH <sub>3</sub> 2-butanone
Amine	-NH <sub>2</sub>	R-NH <sub>2</sub>	CH <sub>3</sub> NH <sub>2</sub> methylamine
Amide	$\begin{array}{c} O \\    \\ -C-NH_2 \end{array}$	$\begin{array}{c} O \\    \\ R-C-NH_2 \end{array}$	CH <sub>3</sub> CH <sub>2</sub> CONH <sub>2</sub> propylamide

## Practice Problems

**Exercise 1:** Using condensed formulas provided, name the following hydrocarbon compounds. It may be helpful to draw the structural formula first.

- $(\text{CH}_3)_2\text{CHCl}$
- $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$
- $\text{CH}_2\text{O}$
- $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}(\text{C}_2\text{H}_5)\text{CH}_3$
- $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CONH}_2$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CONH}_2$
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- $\text{CH}_3\text{CH}_2\text{CHClCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$
- $\text{CH}_3\text{CH}_2\text{CHOCH}_3$
- $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}_2\text{COOH}$
- $\text{CH}_3\text{CH}_2\text{NH}_2$
- $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$
- $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{C}\equiv\text{CCH}_3$
- $\text{CH}_3\text{OCH}_2\text{CH}_2\text{CH}_3$

**Exercise 2:** Draw the condensed formula for each of the following compounds.

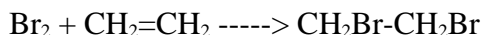
- 2-methyl-2-pentene
- 2-pentanone
- 2-pentyne
- 2,3-dimethyl-2-butene
- 2,2,4,5-tetramethylhexane
- 3-ethyl-4-propylheptane
- 3-hexanol
- 3-octanol
- 3-pentanone
- 3,3,6-trimethylnonane
- 4-ethyl-2-hexyne
- 5-methyl-1-hexane
- ethoxyheptane
- ethylmethanoate
- heptylamide
- hexanal
- hexanol
- methoxyhexane
- methylamide
- octanoic acid
- pentylamine
- propanal
- propanoic acid
- propanoic acid
- propylamine
- propylheptanoate

## Simple Organic Reactions

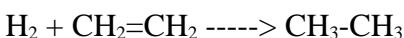
Although organic compounds can undergo a great many reactions, some of the most common types of reactions include addition, substitution, combustion and esterification.

*Addition reactions* generally occur when halogens (halogenation) or hydrogens (hydrogenation) are added to alkenes or alkynes. The net effect is that the double or triple bond is eliminated and the product contains singly-bonded components. This process takes an unsaturated compound and causes it to become saturated. For example,

Bromine added to ethane forms, 1,2-dibromoethane



Hydrogen added to ethane (with high temperature and catalyst) forms ethane.

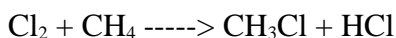


Chlorine added to ethyne forms 1,2-dichloroethene. Excess chlorine will result in 1,1,2,2-tetrachloroethane



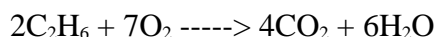
*Substitution reactions* occur when an atom attached to a carbon is removed and something else takes its place. No change in bonding occurs. A common substitution is when a halogen is added to a saturated (only single covalent bonds present) hydrocarbon compound. For example,

Chlorine added to methane forms chloromethane. Often this compound as well as some dichloromethane, trichloromethane and tetrachloromethane will be formed.

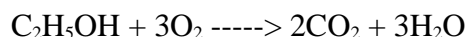


*Combustion reactions* involve the oxidation of an organic compound. Incomplete combustion products are carbon or carbon monoxide and water. The more commonly seen, complete combustion products include carbon dioxide and water.

Ethane burns in oxygen.

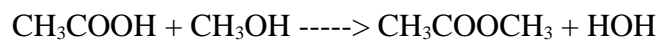


Ethanol is burned in oxygen gas.

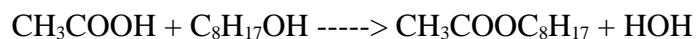


*Esterification reactions* occur when a carboxylic acid is combined with an alcohol. The products which form are an ester and water. The reactions are usually aided by the addition of a small amount of an inorganic acid such as sulfuric acid which is added to act as a dehydrating agent. In essence the hydroxyl group from the alcohol and the acidic hydrogen from the carboxylic acid are removed to form water. The ester group bonds to the alcohol's remaining carbon chain. For example, ethanoic acid (acetic acid) when combined with methanol

(methyl alcohol) will form methoxyethane (methyl acetate) and water.



Ethanoic (acetic) acid is reacted with 1-octanol in the presence of sulfuric acid.



### **Practice Problems**

**Exercise 3:** Predict and balance the following organic reactions

1. Ethanol (ethyl alcohol) is burned completely in air.
2. Propane gas is heated with chlorine gas.
3. Ethanol (ethyl alcohol) and methanoic acid (Formic acid) are mixed and warmed.
4. Ethene gas is bubble through a solution of bromine.
5. Hydrogen gas is added to 2-pentene
6. Octane is burned in oxygen
7. 2 – butene is combined with hydrogen as in the presence of a nickel catalyst.
8. Ethanoic acid is combined with propanol.
9. An excess of chlorine gas is added to pure ethyne (acetylene) gas.
10. A limited amount of liquid bromine is added to an excess of benzene (c6h6)