ORGANIC CHEMISTRY

Organic Chemistry once defined as the study of living compounds, is now defined as the study of compounds containing carbon. The precursor of organic chemistry was the "Vitalistic Theory", the theory held that because living things were created by a special force the compounds in them could not be recreated in the lab. The theory was later disproved by the creation of biological compounds in the lab. Organic compounds can be found in living organisms and in fossil fuels.

In addition to carbon organic compounds can also contain hydrogen, oxygen, nitrogen, and some halogens. (review your bonding capacities and molecular shapes) Organic compounds contain carbon - carbon bonds that form chains and rings, these different forms of bonding arrangements are called allotropes. There are over 3 million different organic compounds, two major reasons for this are the variety of carbon to carbon linkages and all of the possible isomers. (**isomerism** is hydrocarbons with the same formula but different structures)

<u>Differences in Organic and Inorganic Compounds</u>

1. Low M.P. and B.P.; high M.P. and B.P.
2. Flammable; non-flammable
3. Built from a few elements; all elements present
4. Soluble in organic solvents; soluble in water
5. Isomerism very common; isomerism unusual
6. Compounds belong to many classes; mostly acids, bases, and salts.
7. Do not conduct electrical current; conduct electrical current.
8. Reactions complex and slow; reactions simple and fast
9. Side reactions common; usually no side reactions
10. Low yield of desired product; high yield of product
11. Covalent bonding; ionic bonding
12. Over 3 million organic compounds; over 300,000 inorganic compounds.

<u>Miscellaneous Information on Carbon</u>

1. No liquid state for C (it sublimes)

2. All carbon compounds produce CO_2 and H_2O when burned.

3. Carbon exists in 3 solid **allotrophic** (different forms of the same element) forms:

- **Diamond** – crystalline structure whose unit cell is tetrahedral, the repetitive pattern of the strong carbon to carbon bonds makes diamonds strong and hard, good conductors of heat but poor conductors of electricity.
- **Graphite** – bound in layers with weak bonds holding the layers together, used in pencils
- Buckyballs (**Fullerenes**) - think of Epcot, cages of carbon atoms, spherical

4. **Amorphous Carbon**

- **Carbon black** - "soot" is used in rubber tires to make them stronger, paint, printer's ink
- **Coke** - produced by destructive distillation of soft coal; it is denser than charcoal and is an excellent reducing agent; used in extracting metals from ores.
- **Charcoal** - produced by destructive distillation of wood (set a log afire and cover it with sand so it keeps "burning" but with no oxygen)
  Carbides are metal + carbon. Ex.: CaC is calcium carbide.

CLASSIFYING ORGANIC COMPOUNDS

I. Hydrocarbons

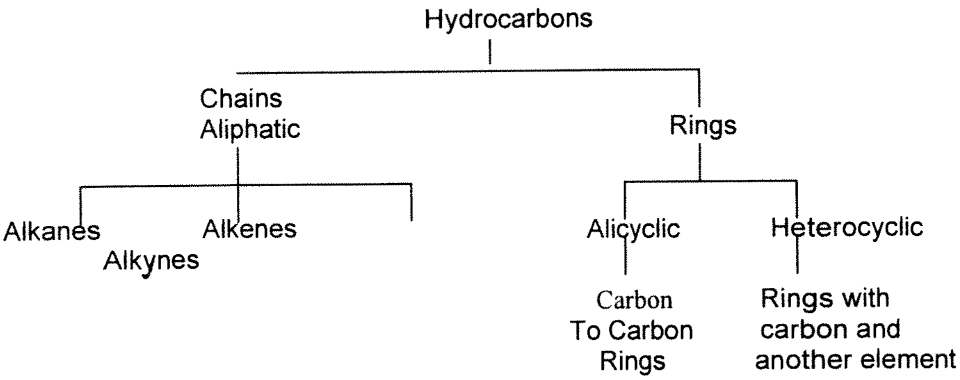
Hydrocarbons contain only 2 elements: carbon and hydrogen. They can be divided into four groups: alkanes, alkenes, alkynes, and aromatic hydrocarbons. The nonaromatic hydrocarbons, that is the alkanes, alkenes, and alkynes, are referred to as aliphatic compounds to distinguish them from aromatic substances. Groups such as the alkanes are called a homologous series because all of the series can be described by the same general formula. A hydrocarbon with only single bonds will hold the maximum number of hydrogen and is referred to as saturated. A hydrocarbon with double or triple bonds can not hold the maximum number of hydrogens and is referred to as unsaturated.

Skeletal carbon structures

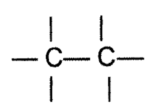
A. **Aliphatic** – carbon atoms bonded in open chains.
- straight or branched
- single (alkanes), double (alkenes), or triple bonds (alkynes)

B. **Alicyclic** – carbon atoms in a closed ring structure.
- multiple or single bonds
- ** - **Aromatic** – special 6 carbon ring structure with alternating single and double bonds.

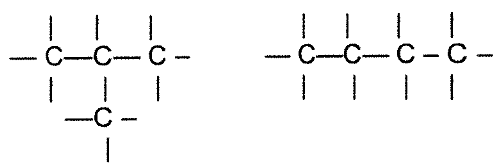
C. **Heterocyclic** – closed structure of carbon and other atoms, such as O.S.N



A. **Alkanes** (saturated) contain only single carbon bonds
General formula is C_nH_{2n+2}

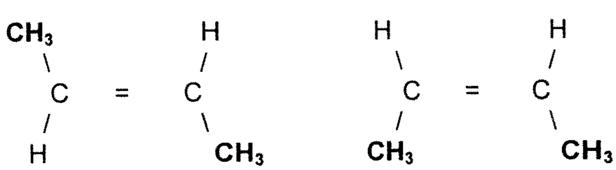


Bond angles are 109.5 ° creating a staggered or zigzag appearance, locked tetrahedrals.
- **Structural isomers** – hydrocarbons with the same formula with different structures.
- Ex.:



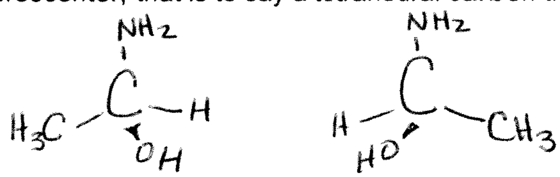
- **Normal** refers to a structure with no branching, labeled n-substance (n-butane).

B. **Alkenes** – (unsaturated) contain one or more double bonds. (C_nH_{2n})
- **geometrical isomers** – the same type of atoms are attached to each other in the same order but the geometry differs. Trans – refers to the branches on the opposite sides of the double bond. Cis – refers to the branches on the same side of the double bond.



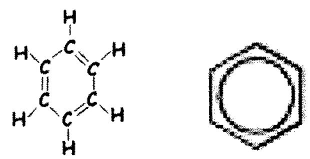
Trans- Cis-

- **Stereoisomers** – the same types of atoms attached to each other in the same order but different orientation of their atoms in space. These structures will have a stereocenter, that is to say a tetrahedral carbon that has four different attachments.



C. **Alkynes** – (unsaturated) contains one or more triple bonds. (C_nH_{2n-2})

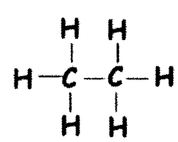
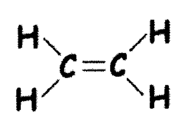
D. **Aromatic** – contains a carbon ring with alternating double and single bonds. (C_6H_6)
- Ex.: benzene

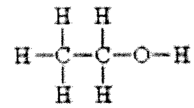
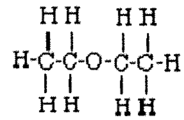
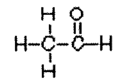
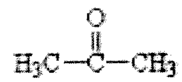
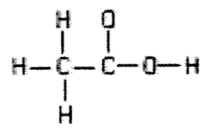
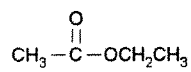
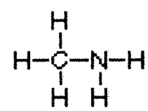


Practice: Complete the following chart.

	Alkanes	Alkenes	Alkynes	Aromatics
Characteristic bonds				
Simplest member				
Common name				____________
General formula				
Name ending				____________
Saturated?				____________

II. Derivatives of Hydrocarbons (contain a functional group)

FAMILY	**FUNCTIONAL GROUP**	**EXAMPLE**		**SUFFIX**
Alkanes	None: carbon and hydrogen only	Ethane		- ane
Alkenes	One or more double bonds between carbons	Ethene		-ene
Alkynes	One or more triple bonds between carbons	Ethyne		- yne

Alcohols R-OH	One or more hydroxide group attached (but does not make it a base)	Ethyl alcohol		- ol
Ethers R-O-R	An oxygen bonded between two carbon	Diethyl ether		- ether
Aldehydes and Ketones R-C-O or R-C-O-R	A double bonded oxygen at the end of the carbon chain or in the middle	Acetaldehyde		- al
		Acetone		
Carboxylic acids RCOOH	The terminal carbon has both a double bonded oxygen and a hydroxide group	Acetic acid		- oic acid
Esters RCOOR	A central carbon has both an single bonded oxygen and a double bonded oxygen	Ethyl acetate		
Amines	Contain Nitrogen	Methylamine		- amine

Polymers – compounds built of a large number of small molecules (monomers) that have reacted with one another. Examples: nylon, rayon, polyethylene, and dacron

IV. **Organic Reactions** – Slow and complex reactions.

A. **Substitutions** – a reaction in which a halogen or functional group replaces a H.

B. **Addition** – a double or triple bond is broken and more hydrogens or other compounds are added.

C. **Oxidation** – adding O_2

D. **Dehydration** – taking away water

E. **Hydration** – adding water

F. **Hydrogenation** – adding H_2

ORGANIC NOMENCLATURE

As you have learned, nomenclature is the process of naming a compound. Just as there were rules for naming inorganic compounds, organic compounds also have very specific rules. Because all organic compounds have the same carbon skeleton the main portion of the name depends upon the number of carbons in the parent chain. Basic items to keep in mind: the **parent chain** refers to the longest continuous chain of carbons, and carbon based branches are named by dropping the –ane and replacing it with –yl.

When naming organic compounds prefixes are used to indicate the number of carbons in the parent chain followed by the appropriate ending (-ane, -ene, -yne). The prefixes used are listed below.

# of carbons	Prefix	# of carbons	Prefix	# of carbons	Prefix
1	Meth-	10	Dec-	19	Nonadec-
2	Eth-	11	Undec-	20	Eicos-
3	Prop-	12	Dodec-	21	Heneicos-
4	But-	13	Tridec-	22	Docos-
5	Pent-	14	Tetradec-	23	Tricos-
6	Hex-	15	Pentadec-	24	Tetracos-
7	Hept-	16	Hexadec-	25	Pentacos-
8	Oct-	17	Heptadec-	30	Triacont-
9	Non-	18	Octadec-		

Branching is common in organic compounds. After identifying the parent chain, identify the end of the chain closest to a branch, this carbon becomes carbon-1, continue numbering the carbon parent chain. The first branch is then identified by the number of the parent carbon it is attached to and then the name of the branch. When naming compounds use commas to separate numbers, hyphens to separate a number and a name, and write all names together.

Rules for Organic Nomenclature

Alkanes:

1. Number the longest parent chain so the branches have the lowest possible numbers.
2. A prefix is used to indicate two or more identical branches.
3. If there are several branches, name them in alphabetical order.

Alkenes and Alkynes:

1. Number the parent chain so that the double or triple bond has the lowest number in the parent chain.
2. The double or triple bond receives the same number as the first carbon involved in the bond.
3. *Cis*- or *Trans*- precedes the name if the structure represents one of these geometric isomers.

Cycloalkanes and Aromatics:

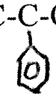
1. For cycloalkanes, add the prefix *cyclo*- to the name of the alkane forming the ring.
2. Aromatic hydrocarbons are normally named as a derivatives of benzene.
3. Number the carbon ring so that any additions have the lowest set of numbers.

your text lists them alphabetically

Branches and Additions:

1. List side chains by order of increasing complexity: *
   First: Halogens
   Smaller number of carbons
   Longer straight chain
   Branched addition that has branching is on the lowest carbon
   Last: Fewer double or triple bonds

2. If a parent chain has two or more side chains in equivalent positions the one assigned the lower number is cited first.
3. If 2 or more side chains are identical – use multiplying prefixes or if they are identical complex groups use prefixes: Di- 2, Tri- 3, Tetra- 4.
4. Benzene groups that are considered branches are named phenol.
   Ex.: C-C-C-C-C-C-C-C-C would be named 5-phenol nonane



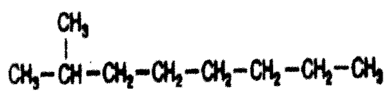
Common Alkyl Substituents and Their Names

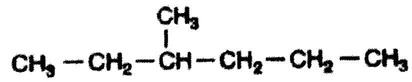
Structure	Name
$--CH_3$	Methyl
$--CH_2CH_3$	Ethyl
$--CH_2CH_2CH_3$	Propyl
| CH_3CHCH_3	Isopropyl
$--CH_2CH_2CH_2CH_3$	Butyl
| $CH_3CHCH_2CH_3$	*Sec*-butyl
H $--CH_2—C--CH_3$ CH_3	Isobutyl
CH_3 $--C—CH_3$ CH_3	*t*-butyl

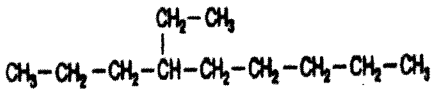
Practice: Illustrate the following compounds.

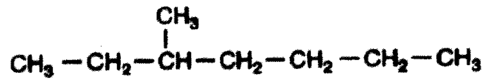
1. 4-methyloctane
2. 3-ethylpentane
3. 3,3,6 – trimethylnonane
4. 2-methyl-3-ethylpentane
5. 3-ethylcyclohexane
6. 4,5-dimethylheptane
7. 3-ethyl-4-propyl-2-heptene
8. 1-chloro-3-hexyne
9. *trans*-2,3-dimethyl-2-butene
10. 4-ethyl-2-hexyne
11. *cis*-2-methyl-3-heptene
12. *Trans*-2-pentene
13. cyclopropane
14. 1,3-dimethylcyclohexane
15. 4-phenyloctane
16. 1-chloro-3methyl-5-ethylbenzene

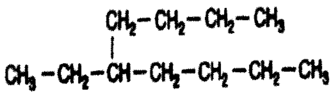
Practice: Name the following structures.

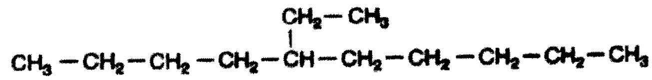
1. 

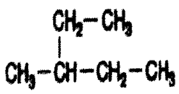
2. 

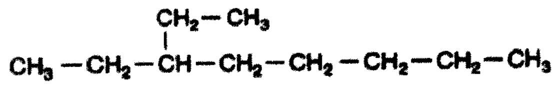
3. 

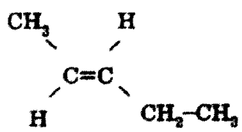
4. 

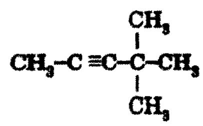
5. 

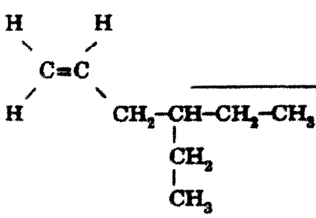
6. 

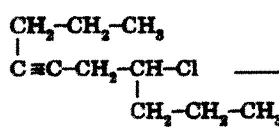
7. 

8. 

9. 

10. 

11. 

12. 

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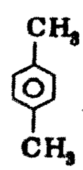
14. 

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