Organic Chemistry Review

What is Organic Chemistry?

- The study of carbon and its bonds
- Its 4 four valence electrons and low molar mass allows it to easily bond with itself
- Only other element that can do this: silicon
- Carbon is more ideal for this because of it low number of shells

IMFA

- Pure alkanes, alkenes, alkynes rely on LDF
- Depending on functional groups, the compound can either have D-D or H-Bond
- With increasing chains or carbons, the effectiveness of D-D and H-Bond decrease
- This is compensated by increase in LDF

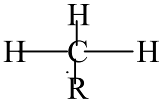
Solubility

- Polar solvent dissolve polar solute
- Nonpolar solvent dissolves nonpolar solution

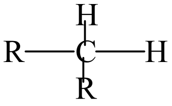
Reactivity

- Reactivity depends completely on functional group
- ALL hydrocarbons can undergo combustion
- Requires oxygen and is self sustaining
  - Complete combustion → Reactant: hydrocarbon and O_2,
    → Product: H_2O, CO2, compound formed f – group
  - Incomplete combustion → Reactant: hydrocarbon and O_2,
    →Product: H_2O, CO, C, compound formed f – group
- Complete combustion → enough oxygen
- Incomplete combustion → lack oxygen (dangerous because of CO produced)

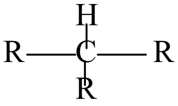
Types of Carbon


$$H-\overset{H}{\underset{R}{C}}-H$$

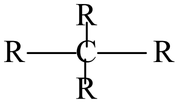
Primary Carbon


$$R-\overset{H}{\underset{R}{C}}-H$$

Secondary Carbon


$$R-\overset{H}{\underset{R}{C}}-R$$

Tertiary Carbon


$$R-\overset{R}{\underset{R}{C}}-R$$

Quaternary Carbon

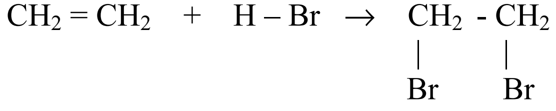
[NOTE: R represents another alkyle group]

Reactions of Organics

1) Substitution: Elements and hydrocarbon exchanges elements or compounds for new compound.

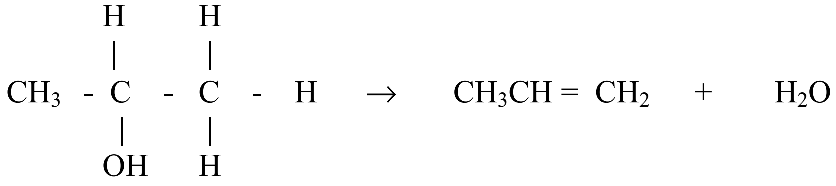
   $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

2) Addition: One molecule adds onto another. (pi bond breaks up to form two stronger sigma bonds)



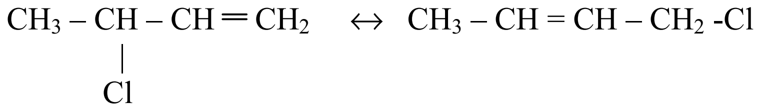
$$CH_2=CH_2 + H-Br \rightarrow \underset{Br}{\underset{|}{CH_2}}-\underset{Br}{\underset{|}{CH_2}}$$

3) Elimination: a hydrocarbon loses a small molecule with the formation of a multiple bond. (Alcohols gives up OH and H)



$$CH_3-\overset{H}{\overset{|}{\underset{OH}{\underset{|}{C}}}}-\overset{H}{\overset{|}{\underset{H}{\underset{|}{C}}}}-H \rightarrow CH_3CH=CH_2 + H_2O$$

4) Rearrangement: Molecule rearranges itself to form new compound with same formula



$$CH_3-\underset{Cl}{\underset{|}{CH}}-CH=CH_2 \leftrightarrow CH_3-CH=CH-CH_2-Cl$$

Bond Fission

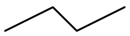
- Heterolytic: one of the atoms retains both the electrons. This requires relatively little additional energy.
- Homolytics: each of the atoms takes an electron. Energy is required to do this and the atom retains this energy. This leaves them reactive.

Reactants

- Nucleophilic: Reactants are substances with non-bonded electron pairs that can be donated.
- Electrophiles: Reactants are electron-paired atoms that are prepared to form new bonds through the electrons of other atoms.
- Homolytics: Radicals with one free electron reacts with another reactant

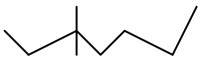
Writing Short Hand Hydrocarbon Structure

- Each vertex or end of a line represents a carbon atom
- Each line represents a bond
- Two line in one spot means a double bond, three line mean triple bond
- The other bond are assumed to be hydrogens



Butane

hex-3 – ene



1,1- dimethyl heptane

Alkanes:

- general formula is C_nH_{2n+2} for chains,
- contains single bonds
- chains (or rings of carbon, in the case of cyclic hydrocarbons), with hydrogen attached to it
- sometimes other alkyl groups (substituents) are attached to it – makes it branched
- serves as the non reactive section of a any system of organic compound

R – X or R – X – R' [general form of organic compounds where R represents alkyl group and R' represents functional group]

- unreactive (C – C bonds and C – H bonds are very strong)
- non-polarity makes it rely solely on LDF for intermolecular force of attraction (low MP, BP)
- Alkanes and hydrocarbons can attach back to back on each other to form rings of cyclo alkanes
- Branched and cyclone alkane a have lower melting points because there is smaller surface area for LDF to take affect
- Can undergo halogenation through the mechanism free radical chain reaction
- A mixture of products are obtained → not very practical for industry
- Reaction take place in uv light → need energy to break halogen bond
- Reaction ends with bonds of: halogen–halogen, alkane–alkane, halogen–alkane
- A free radical reaction is a reaction is a hemolytic reaction where each of the atoms takes an electron. The steps required are:
    1) Initiation
    2) Propagation
    3) Termination
- <u>Fraction Distillation:</u> Process where hydrocarbons are separated by order of their boiling points. The most volatile alkane will rise to the top while the least remain on the bottom
- <u>Cracking</u> → process used to get lower order alkanes and sometimes alkenes
    - Steam Cracking: uses a furnace of temp of 1100K with naphta or gas oil
    - Catalytic Cracking: uses catalyst so that temp of only 800K required (Al_2O_3, SiO_2)
- <u>Octane Number</u>: indicates the ability of an alkane to burn smoothly. High octane number prevents "knocking" → the sound heard when alkane does not burn smoothly in a car engine. Branched akanes have greater octane numbers.
- <u>Reforming:</u> converts chain alkanes to aromatic compounds. If platinum is used as catalyst, it is called <u>platforming</u>

Chain

To name chains place the prefix of the of the number of straight carbons there are and add the suffix –ane (ex: methane, ethane, propane, butane, pentane, hexane, heptane, octane)

Substituent:

Naming substituents is the same as naming chains except add a –yl suffix rather than –ane. Of coarse the substituents can only appear before a main alkane, alkenes, and alkynes group.

Branched

With the presence of substituents, the alkane becomes branched.

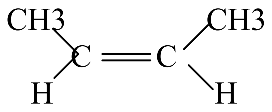
Rings

- C_nH_{2n} for rings
- Rings less stable because of "ring strain" (hard to maintain this position)
- Name them the same as branched except place cyclo in front the main group alkane. Number the cyclo alkane starting from the first substituent going into the path with closest second alkane.
- Exhibit geometrical isomerism: cis— and trans—

Alkenes:

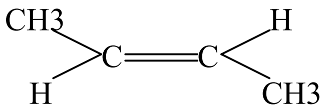
- C_nH_{2n}
- has a double bond(s)
- unsaturated
- the stronger bond (sigma) is very hard to break and is not broken in a chemical reaction.
- the weak bond (pi) is relatively easier to break form two new sigma bond, thus can react easily
- bonds are close together, hence shorter bond length than in alkanes
- overall a double bond is very strong, although the pi –bond is weaker than the sigma—bond
- add an –ene suffix for alkenes and indicate where the double bond is by putting the number where it occurs between the prefix of the longest chain and suffix -ene
- exhibit geometrical isomerism: cis-- and trans-- isomerism
  - the double bond does not allow free rotation
  - there are two places on the carbon where any given group can bond to
  - nature always prefers the trans isomerism

cis



***cis*-2-butene**

trans



***trans*-2-butene**

- we will need to add the cis and trans in the equation
- aside from these, Alkenes follow the same nomenclature rules of alkanes

- Note: Alkenes, and Alkynes can also exist in rings
- Can undergo reaction undergo electrophilic addition reaction where the weak pi bond breaks to form a stronger bond
- There are number of reaction alkenes can undergo, but all are generally the same
- The hydrogen of any addition reaction goes to the carbon with the most hydrogens
- Markovnikov's Rule: the hydrogen attaches to the carbon with the most hydrogens.
- Polymerization is a technique where alkenes are forced into addition reaction with other alkenes to form large chains of carbon

Alkynes

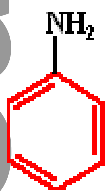
- C_nH_{2n-2}
- Has carbon- carbon triple bonds
- Do not exhibit cis and trans isomerism because of a lack of free rotation
- Bond is shorter than even the alkenes, shortest bond compared to alkanes and alkenes.
- Contains 2 pi bond and 1 sigma bond
- Nomenclature exactly the same as alkenes except –yne suffix

Nomenclature

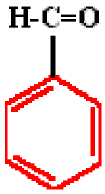
Group	Nomenclature
Alkanes	1. Find the longest chain of carbons, and use this number as the base name 2. Number the chain with the end nearest the first substituent 3. Give the location of the alkyl substituent by the number of the main-chain carbon that it is attached to. 4. Put the Substituents in alphabetical order (i.e. ethyl before methyl)
Alkenes	1. The longest continuous chain containing the double bond defines the parent compound. 2. The carbons are numbered from the end that places the double bond at the lowest possible number. 3. Designate the molecule *cis* or *trans* as necessary. 4. Name the substituents as was done for alkanes. 5. Replace -*ane* ending with -*ene*. If more than one double bond is present, the positions of the bonds are given the lowest possible numbers and *di* (for two) or *tri* (for three) etc. is added before *ene* (e.g. *triene*)
Alkynes	1. The longest continuous chain containing the triple bond is the parent chain. 2. The parent name substitutes "-yne" as a suffix. 3. The position of the –**triple bond** is given the lowest possible number. 4. . Compounds containing more than one –**triple bond** are called "diyne" or "triynes".
Halogen	1. Exactly the same start as alkenes 2. replace -ene with –o 3. place it in front depending on alphabetical order, specify location
Alcohols	1. The longest continuous chain with the **-OH** groups is the parent chain. 2. The parent name substitutes "-ol" as a suffix. 3. The position of the **-OH** group is given the lowest possible number. 4. The ring of a cyclic alcohol is numbered starting at the C bearing the **-OH** group. 5. Compounds containing more than one **-OH** group are called "diols" or "triols".
Amines	1. Find the longest chain attached to nitrogen (parent chain) 2. give lowest number to point of attachment of nitrogen 3. name other substituents on nitrogen in nitrogen alphabetically 4. end name as –amine or begin name as amino-
Aldehyde	1. The longest C chain containing the H—C=O is the parent compound. 2. The parent compound is given the suffix "-al". 3. C-1 is always the H-C=O carbon in aldehydes. 4. C=O has precedence over -OH groups.

Ketone	1. The longest C chain containing the C=O is the parent compound. 2. The parent compound is given the suffix "-one". 3. Ketones, C=O carbon is lowest number possible. 4. C=O has precedence over -OH groups.
Ester	1. Identify the alkyl group that is attached to the oxygen atom 2. Number according to the end closest to the -CO- group regardless of where alkyl substituents are. 3. Determine the alkane that links the carbon atoms together. If there is a separation of a continuous link of carbon atoms due to the oxygen atom, individually name the two alkanes before and after the oxygen atom. The longer structural alkane is the one that should contain the carbonyl atom. 4. The format is as follows: (alkane further from carbonyl) (alkane closest to carbonyl)(parent chain) 5. Change the parent chain -e ending and replace it with an -oate.
Ethers	1. Find longest chain to be parent chain 2. place the other substituent attached to the O group 3. add an -alkoxy- between them, (first the smaller chain, then the larger chain)
Carboxylic Acid	1. The **carboxyl** group always occurs at the end of the molecule, making it C^1. 2. Family name is longest chain containing the carboxyl group 3. Suffix is "-oic acid"
Aromatics	1. If there is only one substituent group on the ring, no number is needed since it will always be on the first carbon atom of the ring. 2. Some single substituted benzenes are named by adding the name of the substituted group as a prefix to the word, benzene. These follow the IUPAC rules for naming 3. When the benzene ring has two substituted groups attached to it, three isomeric forms of the compound are possible. These positional isomers are given the prefixes: ortho- , para- and meta- respectively. 4. When three or more substituent groups are on a benzene ring, the carbon atoms in the ring may be numbered clockwise or counterclockwise starting with one of the substituted groups. The numbering must be done in the direction which results in the lowest possible numbers for the substituted groups. 5. Polycyclic aromatic hydrocarbons or "fused-ring" aromatics.

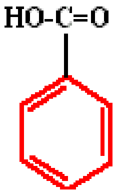
These aromatics must be memorized



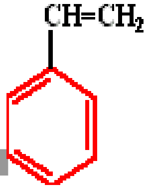
Aniline



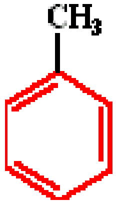
Benzaldehyde



Benzoic acid

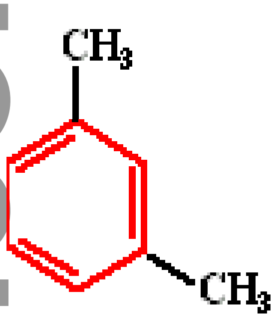


Styrene



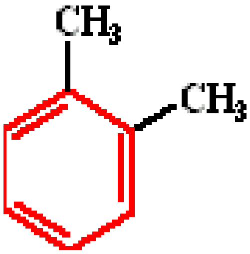
toluene

Position of Aromatics



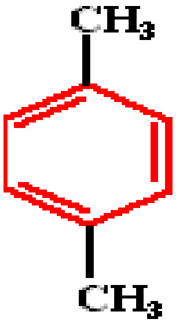
meta

***meta*-Xylene**



ortho

***ortho*-Xylene**



para

***para*-Xylene**