Organic Chemistry

In AP Chemistry, we discuss nomenclature and simple reactions of organic chemistry. This topic could be covered in a year-long college course but we are only covering the basics.

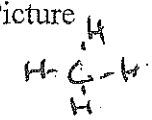
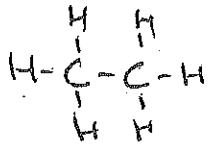
Prefixes

Usually organic compounds are named according to the number of carbon molecules in the main chain.

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

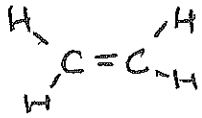
Types of Organic Compounds

1. Alkanes- contain only single bonds, also known as *saturated hydrocarbons*
   Have the general formula C_nH_{2n+2}

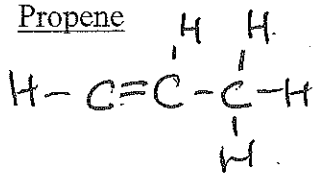
	Formula	Picture
Methane	CH_4	
Ethane	C_2H_6	
Propane		
Butane		
Heptane		

2. Alkenes- contain one or more double bonds, also known as *unsaturated hydrocarbons*
   - Formula can vary depending on the number of double bonds
   - Location of double bond can vary

Example- Ethylene



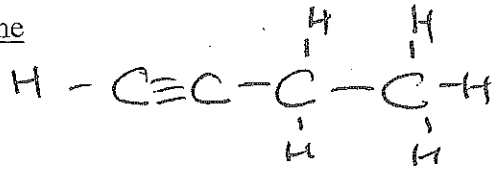
Propene



How many structures can you draw for butene?

3. Alkynes- contain 1+ triple bonds, also *unsaturated hydrocarbons*

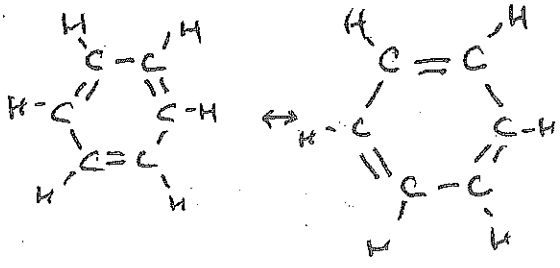
Butyne



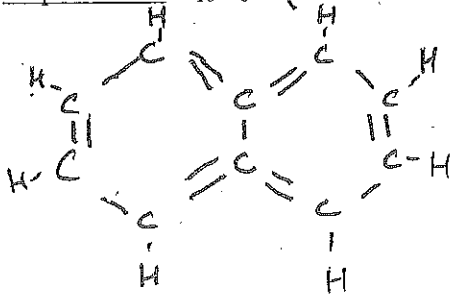
Draw a possible structure for hexyne

4. Hydrocarbon Rings (instead of chains)- this includes a class of compounds known as aromatic hydrocarbons that have a weak intermolecular force. One of these is benzene, C_6H_6.

Benzene (resonant)



Naphthalene $C_{10}H_8$ (also resonant)

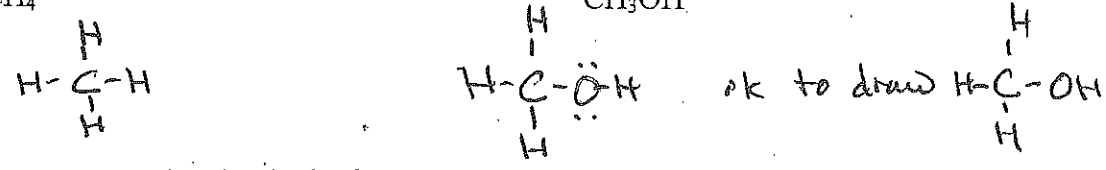


Functional Groups- alterations to a carbon chain that give it a different function

1. Alcohols- to make an alcohol, remove an H and replace it with a *hydroxyl group* (-OH). The hydroxyl group gives the molecule the ability to hydrogen bond and therefore can dissolve in water.

Methane vs Methanol

CH_4 CH_3OH

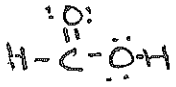


Draw propanol and write its formula:

Ethanol can dissolve both polar and non-polar compounds. Why?

2. Organic acids- contains a *carboxyl group* (-COOH)

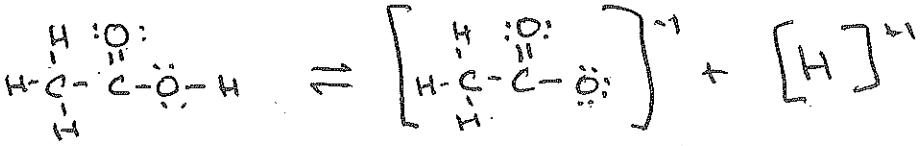
Methanoic Acid is also called Formic Acid (HCOOH)



Ethanoic Acid is commonly called Acetic Acid (CH_3COOH) and is a component of vinegar (the rest is pretty much water).

These acids behave as weak electrolytes. That is, a small fraction of them will dissociate and release a hydrogen ion.

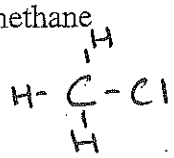
Ex. $CH_3COOH \leftrightarrow CH_3COO^- + H^+$



Write the formula for hexanoic acid and draw its Lewis structure.

3. Halides
   - remove an H and replace it with a halide (F, Cl, Br, I)
   - Add chloro-, fluoro-, etc to the front of the name

Chloromethane or methyl chloride



Iodopropane

4. Amines- remove an H and replace with an *amino group* ($-NH_2$)
   **These behave as weak bases.

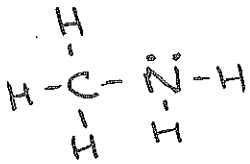
Example

$R—NH_2$

R symbolizes the rest of the molecule (C chain)

The amine is named according to what R is.

Methylamine Ethylamine



5. Aldehydes- contain a *carbonyl group* attached to at least one H

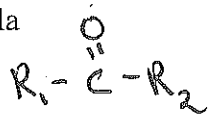
General formula

The most simple is formaldehyde, CH_2O.

More complicated aldehydes have longer C chains in place of the R.

6. Ketones- contain a *carbonyl group* in the middle of a carbon chain

General formula

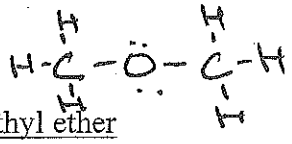


Example- propanone (CH_3COCH_3)

7. Ethers- an oxygen takes place in a carbon chain

R_1—O—R_2

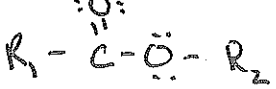
Dimethyl ether- this tells you there are two methyl groups attached to an O



Methyl, ethyl ether

Diethyl ether

8. Esters- an *ester group* (COO) serves as a link in a hydrocarbon chain



Like the ethers, these are names according to their R's.

Dimethyl ester

Isomers

Isomers have the same building blocks but different structures

Example 1- ethanol and dimethyl ether both are C_2H_6O so we write their formulas differently to reveal more about their structures

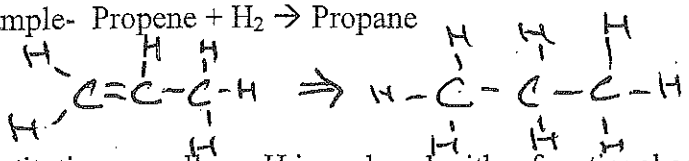
Ethanol (C_2H_5OH) vs dimethyl ether (CH_3OCH_3)

Example 2- How many ways can you draw C_4H_{10}, butane?

Organic Reactions

1 Addition- C=C is broken into a single bond, allowing each C to connect to something else. Or, a CC triple bond can break.

a. Example- Propene + H_2 → Propane



2 Substitution- usually an H is replaced with a functional group (ex. Halide)

3 Polymerization- small chains, or monomers, are linked to form long chains called polymers. When simple sugars are linked to form polysaccharides, it produces water as a product and is called *dehydration synthesis* or *condensation polymerization.*

4 Cracking- larger molecules are broken into smaller ones

5 Oxidation- AKA combustion

Sample AP Questions Regarding Organic Compounds

Example 1 (2002)

Consider the hydrocarbon pentane, C_5H_{12} (molar mass 72.15 g).

(a) Write a balanced equation for the combustion of pentane to yield carbon dioxide and water.

(b) What volume of dry carbon dioxide, measured at 25°C and 785 mmHg, will result from the complete combustion of 2.50 g of pentane?

(c) The complete combustion of 5.00 g of pentane releases 243 kJ of heat. On the basis of this information, calculate the value of ΔH for the complete combustion of one mole of pentane.

(d) Under identical conditions, a sample of an unknown gas effuses into a vacuum at twice the rate that a sample of pentane gas effuses. Calculate the molar mass of the unknown gas.

(e) The structural formula for one isomer of pentane is shown below. Draw the structure for the other two isomers of pentane.

Example 2 (Princeton Review)

In two separate experiments, a sample of an unknown hydrocarbon was burned in air and a sample of the same hydrocarbon was placed in an organic solvent.

(a) When the hydrocarbon sample was burned in a reaction that went to completion, 2.2 g of water and 3.6L of carbon dioxide were produced under standard conditions. What is the empirical formula of the hydrocarbon?

(b) When 4.05 g of the unknown hydrocarbon was placed in 100.0 g of benzene, the freezing point of the solution was measured to be 1.66°C. The normal freezing point for benzene is 5.50°C and the freezing point depression constant for benzene is 5.12 °C/m. What is the molecular weight of the hydrocarbon?

(c) What is the molecular formula of the hydrocarbon?

(d) Write the balance reaction for the combustion that took place in (a).

Example 3- (2003)

Compound Name	Compound Formula	$\Delta H°_{vap}$ (kJ mol^{-1})
propane	$CH_3CH_2CH_3$	19.0
propanone	CH_3COCH_3	32.0
1-propanol	$CH_3CH_2CH_2OH$	47.3

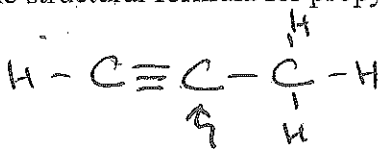
Using the information in the table above, answer the following questions about organic compounds.

(a) For propanone,
  (i) draw the complete structural formula (showing all atoms and bonds)
  (ii) predict the carbon-to-carbon-to-carbon bond angle

(b) For each pair of compounds below, explain why they do not have the same value for their standard heat of vaporization. (You must include specific information about both compounds in each pair).
  (i) propane and propanone
  (ii) propanone and 1-propanol

(c) Draw the complete structural formula for an isomer of the molecule you drew in part (a)(i).

(d) Given the structural formula for propyne below,



  (i) indicate the hybridization of the carbon indicated by the arrow in the structure above
  (ii) indicate the total number of sigma (σ) and pi (π) bonds in the molecule.