Unit 5: Organic Chemistry

Organic chemistry: discipline in chemistry focussing strictly on the study of hydrocarbons – compounds made up of carbon & hydrogen

Organic compounds can contain other elements such as oxygen, nitrogen, sulphur, chlorine, etc., but again are recognized by their make-up of carbon & hydrogen. The different structures that result when the atoms bond to each other leads to a variety of compounds with different properties!

Functional group: a specific structural arrangement of the atoms that result in certain characteristics for the particular molecule

Organic compounds are recognized by the functional groups they contain and we will discuss the various families of organic compounds with reference to the functional group they possess.

<u>Why Carbon?</u>

- Carbon is incredibly abundant and is set up in such a way that it allows for a variety of bonding situations to occur
    1. Carbon has **4 bonding sites** available
    2. Carbon can form single, double or triple bonds
    3. Carbon bonds easily with more electronegative atoms, such as O, N, Cl, and can even form double bonds with atoms such as O & S or triple bonds with N

For all organic compounds, the **IUPAC** nomenclature system is used. IUPAC is a convention used for naming compounds & is recognized throughout the world!

Practice Drawing Carbons

There are 3 ways to draw organic compounds:

1. structural formula: shows all bonds between all the atoms in the molecules
2. simplified structural formula: doesn't show bonds between carbon & hydrogen
3. skeletal formula: molecule drawn as zig-zag branches, only atoms that are not carbon or hydrogen are written
    - carbons assumed at each point & end of a branch
    - enough hydrogens are attached to each carbon to add up to 4 bonds on carbon

Draw a molecule for (a) CH_4 (b) C_2H_6 c) C_5H_{12} in each of the ways described above.

We will now focus on naming and drawing hydrocarbons. I have provided you with a outline of the families of organic compounds which you should refer to see the differences and to observe the properties.

Hydrocarbons (pg 11)

We will first look at a variety of hydrocarbons made up of **only** carbon and hydrogen.

First you must know the prefixes used when counting atoms:

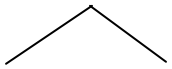
Number of Carbons	**Prefix**	**Number of Carbons**	**Prefix**
1	Meth-	6	Hex-
2	Eth-	7	Hept-
3	Prop-	8	Oct-
4	But-	9	Non-
5	Pent-	10	Dec-

Alkanes

- Hydrocarbons with only *single bonds* between carbon atoms
- All alkanes are named with the suffix *–ane*
- The prefix in a name indicates the number of carbon atoms in the **longest straight chain** in the molecule
- So if you look at the molecules you drew above (a) CH_4 would be methane
  (b) C_2H_6 would be ethane and c) C_5H_{12} would be pentane

<u>Example 1.</u>

Name the following:

a) C_3H_8 b) C_8H_{18} c) $CH_3 – CH_2 – CH_2 – CH_3$ d) 

Example 2.

Draw a structural diagram for

a) Octane b) methane c) butane d) nonane

Branched Alkanes

- Any branches in the carbon chain are named with the prefix for the branch, followed by the suffix *–yl*
- If more there is more than one branch that is the same, then use prefixes, di-, tri- tert-, etc. to represent this in the name
- The name of a branched alkane must also indicate the point of attachment of the branch (this is done by assigning numbers to the carbons in the longest chain)
- The naming system always uses the lowest numbers possible to denote a position on the chain
- All numerals are separated by commas
- Numerals & letters are separated by hyphens
- Names of branches & parent chains are not separated

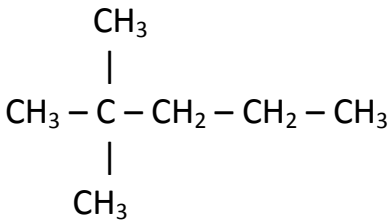
Example 1.

Name the following compounds:

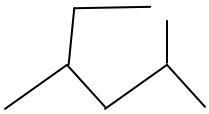
(a) $CH_3 – CH(CH_3) – CH_2 – CH_3$

(b) $CH_3 – CH_2 – CH(CH_3) – CH(CH_2CH_3) – CH_2 – CH_3$

(c)



(d)



Example 2.

Draw a structural diagram for

(a) 3-ethyloctane (b) 2,3-methylbutane (c) 2,2,3-trimethyl hexane

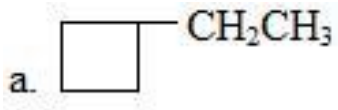
Practice Naming Alkanes Worksheet #1

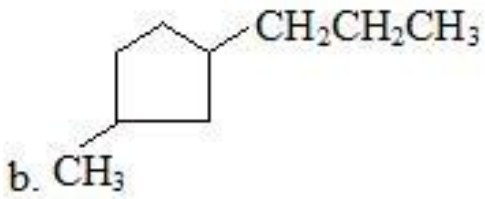
Cyclic Alkanes

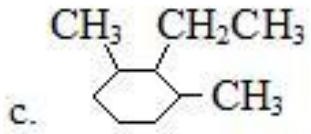
- Alkanes that form rings
- The carbon atoms that form the ring form the parent chain
- Use the prefix *cyclo*- in front of the parent chain name
- Follow the same rule as above for naming the branches

Example 1.

Name the following compounds:

a. 

b. 

c. 

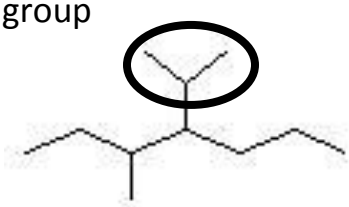
Example 2.

Draw a structural diagram for

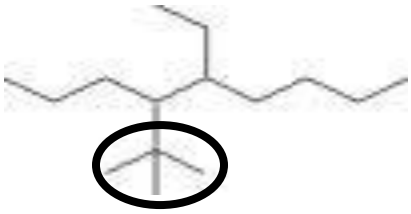
(a) 1-methylcyclopropane (b) 1,3 – diethylcyclohexane

Some Common "Interesting" Naming Structures you Could See

1. isopropyl – when a branch is made of a propyl group that is attached at the 2nd carbon of the propyl group



2. tertiary-butyl (or t-butyl) - when a branch is made of 1,1-dimethylethane



Practice pg 15 #1-2

Alkenes

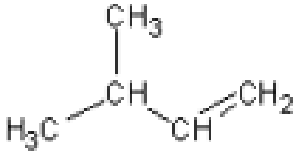
- Hydrocarbons with *double bonds* between carbon atoms
- All alkenes are named with the suffix *–ene*
- All rules used for alkanes apply here as well
- Parent-chain must be the alkene!
- Numbers represent location of double bond
- For multiple bonds, use prefixes di, tri, etc, as before

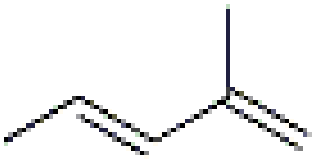
Alkynes

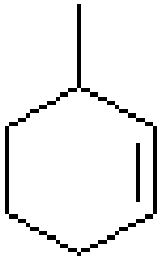
- Hydrocarbons with *triple bonds* between carbon atoms
- All alkynes are named with the suffix *–yne*
- Follow all the same rules as for alkenes

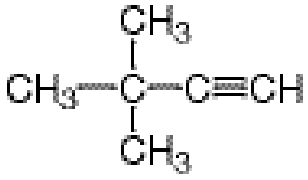
<u>Example 1.</u>

Name the following compounds:









Example 2.

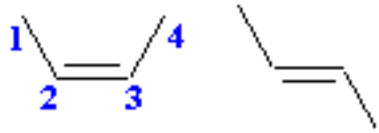
Draw a structural diagram for:

(a) ethyne (b) 4-methyl – 1- pentene (c) 1,3-butadiene

Practice pg18 #3-6

More Specifically About Alkenes

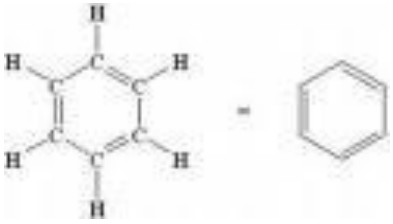
- Alkenes can have two shapes:



- Both of the above molecules are 2-butene, but they have a different shape
- These are known as **isomers:** molecules with the same molecular formula, but a different shape
- And of course, since they are shaped different, they react differently, and you must distinguish between the two!
- The one on the left is **cis-2-butene** and the one on the right is **trans-2-butene**
- Use the prefix *cis*- (or Z) for any alkene that has the "boat" type shape
- Use the prefix *trans*- (or E) for any alkene that has the "zig-zag" type shape

Aromatic Hydrocarbons

- 1,3,5-hexatriene



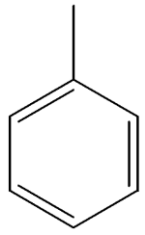
- Better known as **benzene**, and is often simply drawn as:

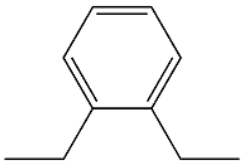
- If there is only one group attached to the benzene ring, we do not have to assign a number since there is no beginning or end to the ring, so we assume it to be 1
- However, if there is more than one group be must assign numbers as we did before
- The benzene ring should be considered as the parent chain if possible, but if naming becomes too complicated, it may be considered as a branch
- **Phenyl**: name used to refer to a branch made of benzene

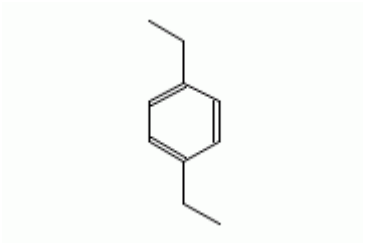
<u>Example 1.</u>

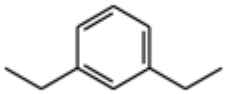
Name the following compounds:

(a) (b) (c) (d)









****note:** b-d are all isomers of diethylbenzene! They all have the same formula, but look and react very differently!!

Example 2.

Draw a structural diagram for:

(a) 1-ethyl-2,4-dimethylbenzene (b)4-phenyl-3-propyl-1-hexene

Practice pg 21#7-8a-c

Organic Halides (pg 32)

Organic halides: compound of hydrogen & carbon in which one or more hydrogen atoms have been replaced by a halogen atom

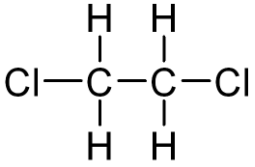
To name organic halides:

- The halogen is considered as an attachment/branch to the parent chain
- Halogen name is shortened to fluoro-, chloro-, bromo- or iodo-
- Numbers used as before

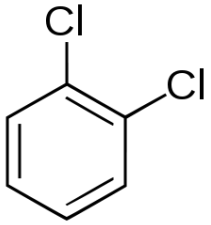
Example 1.

Name the following compounds:

(a)



(b)



Example 2.

Draw a structural diagram for:

(a) 2,2,5-tribromo-5-methylhexane (b) 2-bromo-4-chloroheptane

Practice pg 33 #1-2 ***(don't do #1k)***

Practice Naming Exercise 2

Alcohols and Ethers (pg 38)

Alcohols: organic compound characterized by the prescence of a hydroxyl functional group: R – OH

Naming:

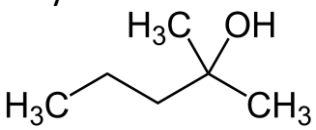
- Alcohols are named with the suffix *–ol* added to the alkane name
- Numbering rules still apply!

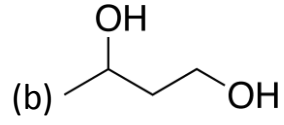
Types of Alcohols

- Primary alcohols (1°) – hydroxyl group attached to carbon that is attached to only **one other carbon**
- Secondary alcohols (2°) - hydroxyl group attached to carbon that is attached to **two other carbons**
- Tertiary alcohols (3°) - hydroxyl group attached to carbon that is attached to **three other carbons**
- These will be important to know later when we look at reactions of alcohols

Example 1.

Name the following compounds and identify if it is a primary, secondary or tertiary alcohol:

(a) 

(b) 

Example 2.

Draw a structural diagram for and identify if it is a primary, secondary or tertiary alcohol:

(a) 3-ethyl-2-pentanol (b) 2,3-dimethyl-2-butanol

Practice pg 41#1-3

Ether: organic compound with two alkyl groups attached to an oxygen atom: R – O – R'

Naming **there are 2 ways**:

- Name both groups with their alkyl name
- Put the smaller group first
- Add the word ether to the end
- Use prefix *di-* if both groups are the same

OR

- Write smaller group name first (without an ending)
- Write name of larger group name last
- Insert "*oxy*" in between the two names

Example 1.

Name the following compounds in two different ways:

(a) $CH_3CH_2CH_2OCH_2CH_3$ (b) $CH_3(CH_2)_2OCH_2CH_2CH_3$

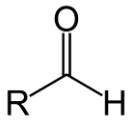
Example 2.
Draw a structural diagram for:
(a) methyl ethyl ether (b) ethoxybutane

Practice pg 46 #11

Aldehydes and Ketones

carbonyl group: functional group containing a carbon atom double bonded to an oxygen atom; C = O

Aldehyde: organic compound with a terminal carbonyl functional group; R-CHO

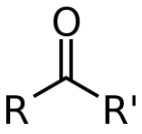


Aldehyde groups always occur at the end of the chain!

Naming:

- Aldehydes are named with the suffix *–al* added to the alkane name

Ketone: organic compound characterized by a carbonyl group in the middle of the compound

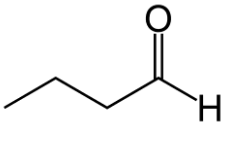


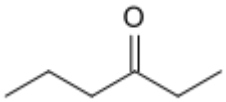
Naming:

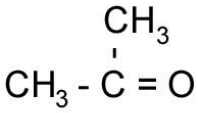
- Ketones are named with the suffix *–one* added to the alkane name
- the number refers to where the carbonyl group occurs in the compound

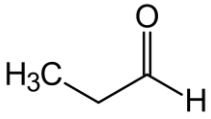
Example 1.

Name the following compounds:

(a) 

(b) 

(c) 

(d) 

Example 2.

Draw a structural diagram for:

(a) heptanal (b) 2-pentanone (c) cyclohexanone

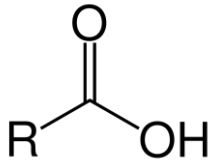
Practice pg 51 #1-3

Note: Common Names:

1. formaldehyde – methanal
2. acetone – propanone
3. acetylaldehyde – ethanal

Carboxylic Acids and Esters (pg 58)

carboxylic acids: characterized by presence of carboxyl group – COOH

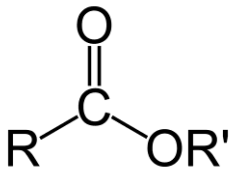


Carboxylic Acid groups always occur at the end of the chain!

Naming:

- change alkane name to "*-oic*" followed by the word acid

Esters: characterized by a carbonyl group bonded to an oxygen atom

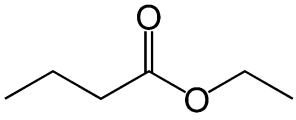


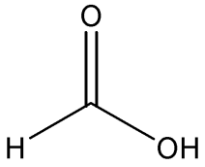
Naming:

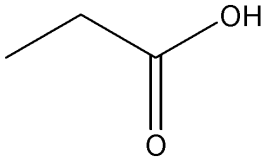
- name the alkyl group attached to the oxygen first
- name the other group with the alkane name and the "*-oate"* ending

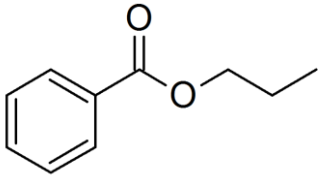
<u>Example 1.</u>

Name the following compounds:

(a) 

(b) 

(c) 

(d) 

<u>Example 2.</u>

Draw a structural diagram for:

(a) ethanoic acid (acetic acid) (b) butyl propanoate

Practice pg 60 #1-2

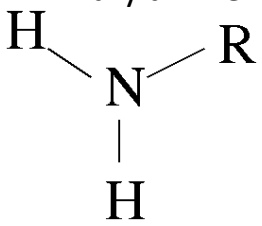
Practice pg 66 #11-12 ***(only name, don't do other parts for the question)***

<u>Amines and Amides (pg 69)</u>

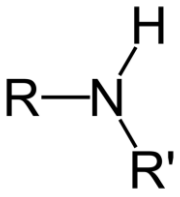
Amine: ammonia (NH_3) in which one or more H is substituted with a alkyl or aromatic group

There are 3 types of amines:

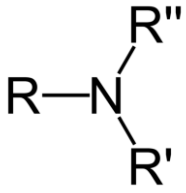
Primary amine



Secondary amine



Tertiary amine



Naming:

There are two ways:

1. use prefix "*amino-"* in front of alkane name
2. use alkyl name with suffix *"-amine"*

The first method is most common and is simpler. Other notes about naming:

- use numbers to indicate location of amino group
- for 2° and 3° amines, use the *N*-prefix to denote the substituted groups on the N atom of the amino group

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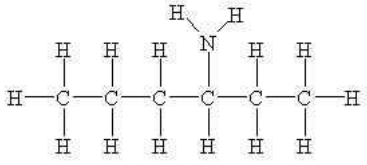
Example 1.

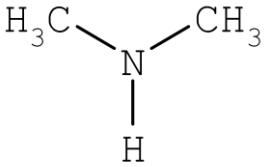
Name the following compounds:

(a)

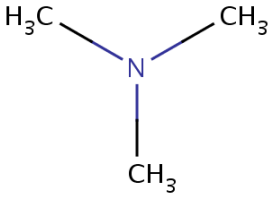
(b)



(c)



(d)

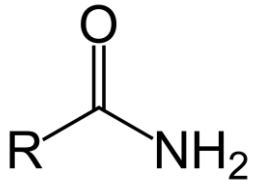


Example 2.
Draw a structural diagram for:
(a) N-methyl-1-aminobutane (b) N,N-dimethyl-2-aminopropane

(c) 2-chloro-N,N-dimethyl-4-aminohexane

Practice pg 72 #1-3

Amide: characterized by the prescence of a carbonyl group (C=O) bonded to a nitrogen atom



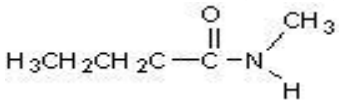
And of course you can get primary, secondary and tertiary amides by replacing the H with alkyl groups.

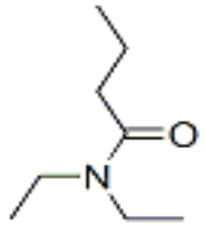
Naming:

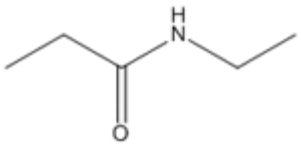
- name in alkyl group attached to nitrogen first
- name the other group with the alkane name and the "*-amide"* ending
- use "N" to represent groups attached to the N

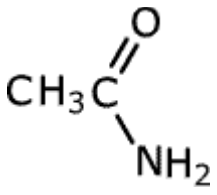
Example 1.

Name the following compounds:

(a) 

(b) 

(c) 

(d) 

Example 2.

Draw a structural diagram for:

(a) N-isopropyl ethanamide (b) N,N-diethyl acetamide

Practice pg 76#4-6

Organic Nomenclature Worksheet

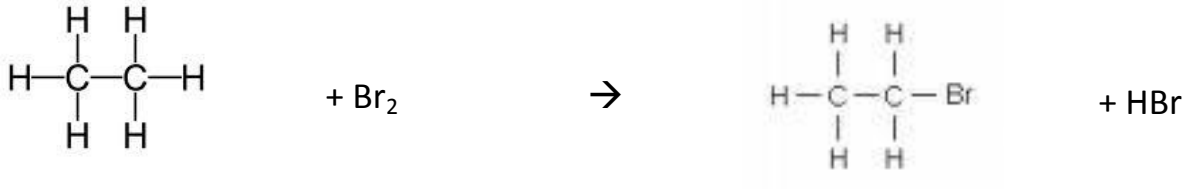
Complete Organic Chemistry Worksheet

Reactions of Organic Compounds

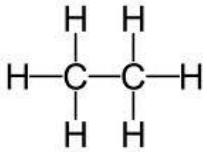
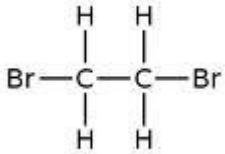
There are a number of reactions to prepare the various compounds above, but we focus on 6 main categories.

1. **substitution reaction:** hydrogen atom is replaced with another atom or group of atoms

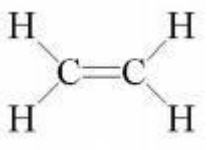
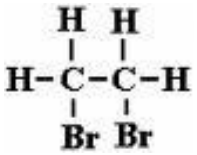
eg.

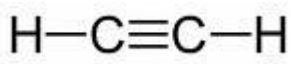
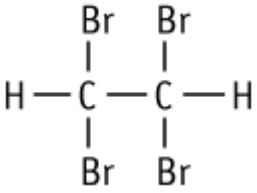


You can even have a double substitution!

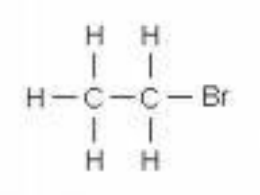
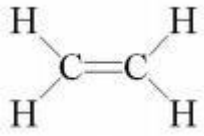
 + Br_2 →  + H_2

2. **addition reaction:** reaction with alkenes/alkynes where a molecule is added to the double/triple bond

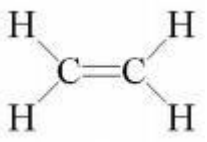
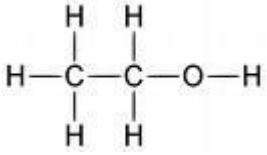
 + Br_2 → 

 + $2Br_2$ → 

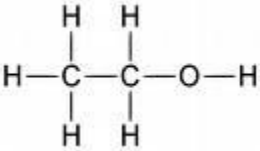
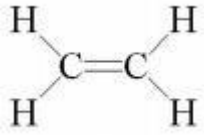
3. **elimination reaction:** loss of a small molecule from a larger molecule; usually forms a double/triple bond

 + OH^- →  + H_2O + Br^-

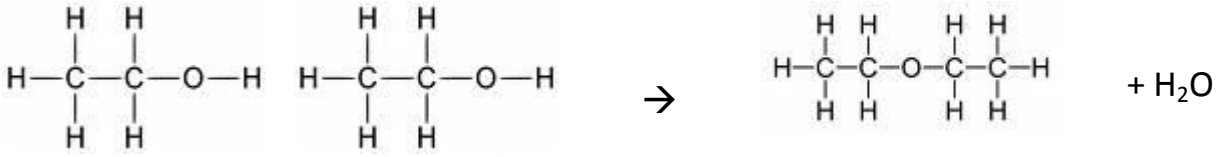
4. **hydration reaction:** addition of a water molecule

 + H_2O → 

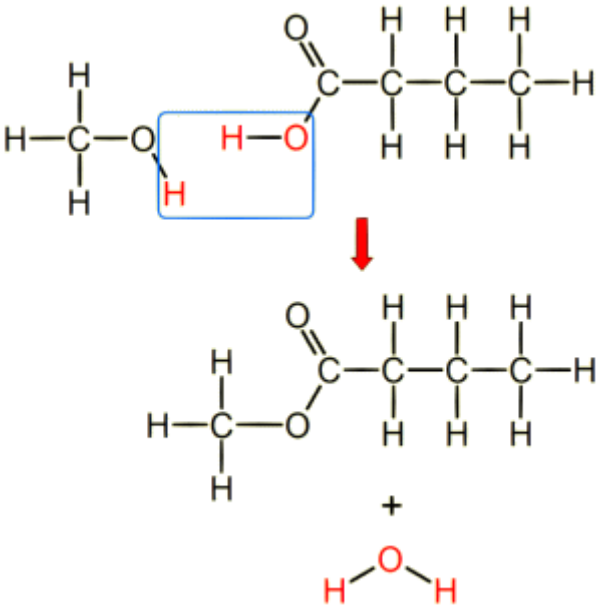
5. **dehydration reaction:** removal of a water molecule

 →  + H_2O

6. **condensation reaction:** two molecules combining to form one & release water



You can also form esters by reacting carboxylic acid and an alcohol (called esterification).



Practice *pg 27#1*
Pg 30#4
Pg 31#3
Pg 37#6 (practice)
Pg 68#3