Organic Chemistry

Unit 10

Organic Chemistry

Originally, organic chemistry was the study of substances from living things

1828: Friedrich Wöhler synthesized urea and a new definition of organic was needed

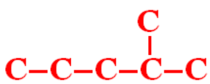
The modern definition of organic chemistry is the study of carbon and its compounds

There is a vast number of organic compounds due to the chemical properties of carbon

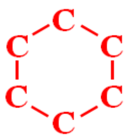
- carbon *concatenates* or forms long chain molecules

  C–C–C–C–C

- carbon forms *branched* chains

- carbon forms *rings*

- carbon forms *multiple* bonds (single, double, or triple bonds)

  C–C, C=C, C≡C

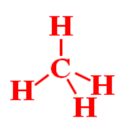
Hydrocarbons:

Common characteristics of hydrocarbons

- generally nonpolar
  - soluble in nonpolar solvents like benzene of hexane
  - not soluble in polar solvents like water
- usually are non-electrolytes
- generally have low melting points
- chemical reactions are slow compared to inorganic reactions
  - organic reactions have a high activation energy, E_a

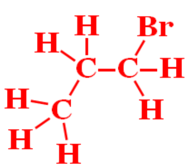
These properties and characteristics are generally due to the unique bonding of carbon

$^{12}_{6}C$



- electron configuration = 2 – 4
- four valence electrons
- can form four covalent bonds
- four bonds result in a *tetrahedral* structure
- carbon compounds are grouped by similarities
  - hydrocarbons contain only C and H atoms
    - homologous series (having the same relative structure)
      - alkanes C – C $C_n - H_{2n+2}$
      - alkenes C = C $C_n - H_{2n}$
      - alkynes C ≡ C $C_n - H_{2n-2}$
  - functional groups

Types of organic formulas:



structural

C_3H_7Br

molecular

C–C–C–Br

backbone

$CH_3CH_2CH_2Br$

condensed

skeletal

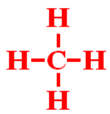
Hydrocarbon Nomenclature – these compounds contain only H and C

Homologous series of the hydrocarbons – organic compounds that differ by the number of carbon atoms in their longest chains (or, differ by the number of CH_2 units)

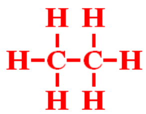
The suffixes (endings) of each series identifies the bond order (single, double, or triple)

Alkanes (C – C) C_nH_{2n+2} all bonds are single bonds

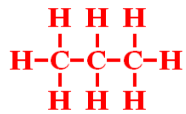
Examples of the alkane hydrocarbon homologous series (Table Q)



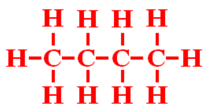
methane



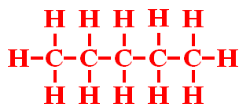
ethane



propane



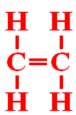
butane



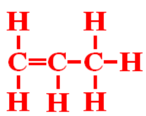
pentane

Alkenes (C = C) C_nH_{2n} has one double bond

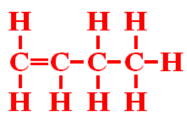
Examples of the alkene hydrocarbon homologous series (Table Q)



ethene



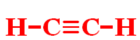
propene



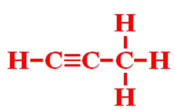
but-1-ene

Alkynes (C ≡ C) C_nH_{2n-2} has one triple bond

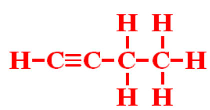
Examples of the alkyne hydrocarbon homologous series (Table Q)



ethyne



propyne



but-1-yne

The prefixes (beginnings) of each name gives the number of carbon atoms in the longest chain (Table P)

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

Naming alkanes

1. Count the number of C atoms in the longest chain
2. Use the prefix to start the name (Table P)
3. Add the 'ane' ending (Table Q)

Example of the alkane nomenclature:

Name $CH_3CH_2CH_2CH_3$ 1) 4 C atoms 2) but 3) + ane butane

Go on to the next page

Naming alkenes and alkynes

1. Count the number of C atoms in the longest chain
2. Use the prefix to start the name (Table P)
3. Add the multiple bond position (use the lowest address)
4. Add the 'ene' or 'yne' ending (Table Q)

Examples of the alkene and alkyne nomenclature:

Name $CH_2=CHCH_2CH_3$

1) 4 C atoms 2) but- 3) + 1- 4) + ene but-1-ene

the Regents will sometimes use 1-butene

Naming branched alkanes

1. Start with the numerical address (lowest number) of the branch position
2. Use a prefix to identify the branch length (Table P)
3. Add 'yl' to finish the branch name
4. Use the prefix to identify the length of the main chain name (Table P)
5. Add the 'ane' ending

Examples of the alkene and alkyne nomenclature:

Name $CH_3CH_2CH(CH_3)CH_3$

1) 2nd C atom = 2- 2) meth+yl 3) + but 4) + ane 2-methylbutane

notice that the condensed formula showed the methyl on the 3rd C from the left end but the correct name recounts as the 2nd carbon from the right end

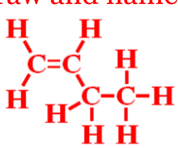
Isomerism

Isomers have the same molecular formulas, but different structures and properties

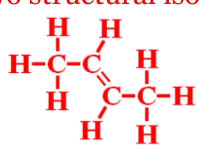
NYS Regents calls this type of isomer a *structural isomer*

IUPAC recommends that structural isomers be called *constitutional isomers*

Draw and name the two structural isomers of butene



1-butene
but-1-ene

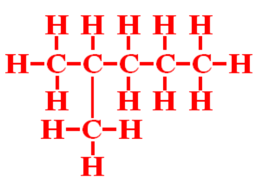


2-butene
(2*E*)-but-2-ene [IUPAC name, shown]
(2*Z*)-but-2-ene [not shown]

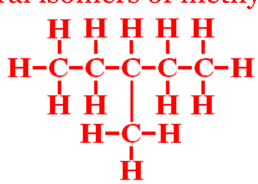
A third structural isomer, 2-methylprop-1-ene also exists, but it is a propene

1-butene		2-butene	
−185.3°C	M.P.	−105.5°C	[2*E*]
−6.47°C	B.P.	−3.7°C	[2*E*]

Draw and name the two structural isomers of methylpentane



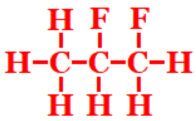
2-methylpentane



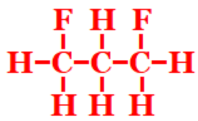
3-methylpentane

2-methylpentane		3-methylpentane
−160°C	M.P.	−163°C
60°C	B.P.	63°C

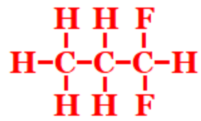
Draw and name the four structural isomers of difluoropropane



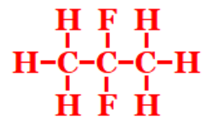
1,2-difluoropropane



1,3-difluoropropane



1,1-difluoropropane



2,2-difluoropropane

Condensed formulas are used to write a type of structural formula in word processors

Rules for writing condensed formulas

1. The entire formula is must be written in one line of type
2. All the atoms bonded to a C atom will be written to the right of that C atom
3. Polyatomic funcional groups or branches in the middle of the chain are parenthetical
4. If there is only one functional group on C1, C1 will be to the extreme right

Examples of writing condensed formulas:

Write the condensed formula for propan-1-ol (1-propanol):

Start with propane:	$CH_3CH_2CH_3$
Substitute the ol (-OH) on the last C:	$CH_3CH_2CH_2OH$

Write the condensed formula for propan-2-ol (2-propanol):

Start with propane:	$CH_3CH_2CH_3$
Substitute the ol (-OH) on the central C:	$CH_3CH(OH)CH_3$

Write the condensed formula for 2-methylpropanal:

Start with propane:	$CH_3CH_2CH_3$
Substitute the methyl ($-CH_3$) on the central C:	$CH_3CH(CH_3)CH_3$
Substitute the al (=O) on the last C:	$CH_3CH(CH_3)COH$

Functional Groups

A functional group is a particular arrangement of a few atoms that results in similar molecules with a specific set of chemical properties (e.g., alcohols)

Most organic compounds are a hydrocarbon backbone plus one or more functional groups

- the hydrocarbon is represented by the letter 'R'
- nine common functional groups are shown in Table R

Halide	(F, Cl, Br, I)	R-X	$CH_3CHClCH_3$	2-chloropropane
Alcohol	-OH	R-OH	$CH_3CH_2CH_2OH$	1-propanol
Ether	-O-	R-O-R'	$CH_3OCH_2CH_3$	methyl ethyl ether
Aldehyde	O ‖ -C-H	O ‖ R-C-H	O ‖ CH_3CH_2COH	propanal
Ketone	O ‖ -C-	O ‖ R-C-R'	O ‖ $CH_3CCH_2CH_2CH_3$	2-pentanone
Acid	O ‖ -C-OH	O ‖ R-C-OH	O ‖ CH_3CH_2COH	propanoic acid
Ester	O ‖ -C-O-	O ‖ R-C-O-R'	O ‖ $CH_3CH_2COCH_3$	methyl propanoate
Amine	| -N-	R' | R-N-R"	$CH_3CH_2CH_2NH_2$	1-propanamine
Amide	O ‖ | -C-NH	O R' ‖ | R-C-NH	O ‖ $CH_3CH_2CNH_2$	propanamide

Functional Group Properties

Name the three intermolecular forces (IMFs) in order from strongest to weakest

- hydrogen bonds
- dipole – dipole interactions
- van der Waal's interactions

Which intermolecular forces would result in the highest boiling points?

- hydrogen bonds (they are the strongest forces, it takes more energy to break them)

Which functional groups would be expected to have the highest boiling points?

- acids and alcohols
- followed by amides and amines

These are the only functional groups that can form hydrogen bonds

Why do acids and alcohols tend to have higher boiling points than amides and amines?

- O is more electronegative than N and forms stronger hydrogen bonds

Why do molecules with functional groups have the higher boiling points than hydrocarbons?

- the functional groups cause molecules to be polar

Why are molecules with functional more soluble in water than hydrocarbons?

- the functional groups cause molecules to be polar

Organic Reaction Types

- addition: $CH_2{=}CH_2 + HBr \rightarrow CH_3CH_2Br$
- substitution: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
- polymerization: $n[CH_2{=}CHCl] \rightarrow [CH_2CHCl]_n$
- esterification: $CH_3OH + CH_3COOH \rightarrow CH_3OOCCH_3 + H_2O$
- fermentation: $C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$
- saponification: fat + NaOH → soap + water
- combustion: $CH_3CH_2CH_3 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$