A (very) Little Organic Chemistry

Carbon Chemistry

- Electronic structure leads to a variety of bonding possibilities
  - Infinite number of possible combinations!

Organic Chemistry

Rule of thumb: Carbon typically forms four bonds!

- Four possible combinations of single, double & triple
- Stability and movement of bonds in carbon compounds.

Allotropic forms of carbon:

- Diamond - sp^3
- Graphite - sp^2
- Fullerenes (buckyballs & buckytubes) - "sp^2"

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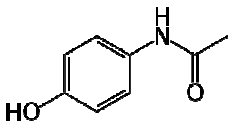
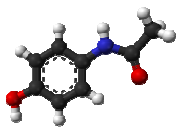
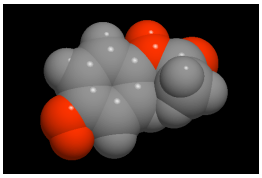
Organic Chemistry

- Many compounds are built around the carbon atom
  - Organic Chemistry focuses on these compounds
    - Contain carbon and other atoms such as H, O, N, S, P…
    - >10 million compounds
  - Natural or "synthetic"
  - Huge variety due to many bonding possibilities for carbon
- Approaches for representing organic compounds
  - Examples: hexane, acetaminophen ($C_8H_9NO_2$)







Functional Group Chemistry

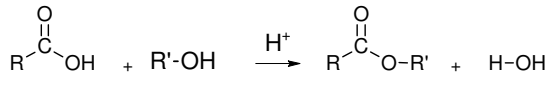
- Even though there are many organic compounds, it is possible to categorize compounds by looking at how the atoms are arranged
  - **Functional Group** – portion of a compound that has a characteristic arrangement of atoms and characteristic properties and reactivity.

- Functional Groups are the key to understanding organic chemistry!

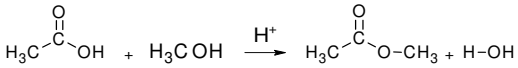
Functional Group	Formula	Structure	Properties
Alkane	C-C and C-H single bonds		
Alkene	R_2-C=C-R_2		
Alkyne	R-C≡C-R'		
Alcohol	R-OH		
Ether	R-O-R'		

Functional Group Chemistry

- Because of common reactivity of functional groups, it is possible to predict reactivity of organic compounds
- EXAMPLE: Ester formation: Esters can be formed by the dehydration reaction of an alcohol and a carboxylic acid.



- "R" can be any group



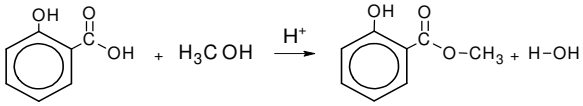


Table 9.4 Selected Organic Functional Groups

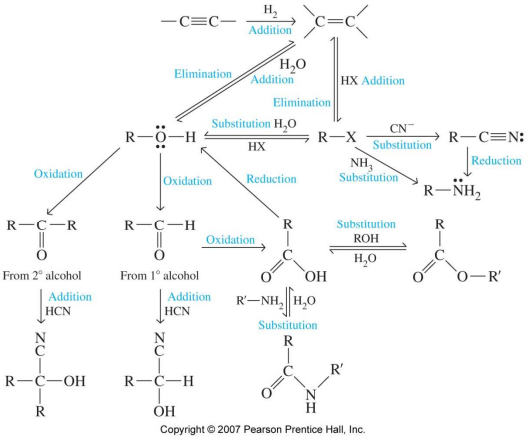
Name of Class	Functional Group*	General Formula of Class
Alkane	None	R—H
Alkene	—C=C—	$R_2C=CR_2$
Alkyne	—C≡C—	RC≡CR
Alcohol	—C—OH	R—OH
Ether	—C—O—C—	R—O—R′
Aldehyde	—C(=O)—H	R—C(=O)—H
Ketone	—C(=O)—	R—C(=O)—R′
Carboxylic acid	—C(=O)—OH	R—C(=O)—O—H
Ester	—C(=O)—O—C—	R—C(=O)—O—R′
Amine	—C—N—	R—N(—H)—H; R—N(—H)—R′; R—N(—R′)—R″
Amide	—C(=O)—N—	R—C(=O)—N(—H)—H; R—C(=O)—N(—R′)—H; R—C(=O)—N(—R′)—R″

* Neutral functional groups are shown in green, acidic groups in red, and basic groups in blue.

Functional Group Chemistry

So, we can build larger, more complicated molecules by taking advantage of functional group reactivity!

- Regardless of whether we're talking about small molecules like methanol or huge molecules like proteins, behavior typically boils down to functional group reactivity!



Identification and Naming of Organic Compounds

Two key criteria

1. Types of functional groups present
2. Length of carbon backbone
   - Prefix tells length of carbon chain
   - Virtually any organic compound can be named based on rules developed from these criteria.

Name	Molecular Formula	Structural Formula	Isomers
meth**ane**	CH_4	CH_4	1
eth**ane**	C_2H_6	CH_3CH_3	1
prop**ane**	C_3H_8	$CH_3CH_2CH_3$	1
but**ane**	C_4H_{10}	$CH_3CH_2CH_2CH_3$	2
pent**ane**	C_5H_{12}	$CH_3(CH_2)_3CH_3$	3
hex**ane**	C_6H_{14}	$CH_3(CH_2)_4CH_3$	5
hept**ane**	C_7H_{16}	$CH_3(CH_2)_5CH_3$	9
oct**ane**	C_8H_{18}	$CH_3(CH_2)_6CH_3$	18
non**ane**	C_9H_{20}	$CH_3(CH_2)_7CH_3$	35
dec**ane**	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$	75

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Organic Nomenclature:

IUPAC Rules for Alkane Nomenclature:

1. Find and name the longest continuous carbon chain.
2. Identify and name groups attached to this chain.
3. Number the chain consecutively, starting at the end nearest a substituent group.
4. Designate the location of each substituent group by an appropriate number and name.
5. Assemble the name, listing groups in alphabetical order.

The prefixes di, tri, tetra etc., used to designate several groups of the same kind, are not considered when alphabetizing.

Alkyl Substituents:

Group	Name	Group	Name
CH_3–	Methyl	$CH_3CH_2CH_2CH_2$–	Butyl
C_2H_5–	Ethyl	$(CH_3)_2CHCH_2$–	Isobutyl
$CH_3CH_2CH_2$–	Propyl	$CH_3CH_2CH(CH_3)$–	sec-Butyl
$(CH_3)_2CH$–	Isopropyl	$(CH_3)_3C$–	tert-Butyl

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Means of representing organic compounds:

1. **Molecular Formula:** Identifies only number and types of atoms present, no structural information.

   Ex: C_4H_{10}
2. **Structural Formula:** Also gives structural information (Lewis structure). Allows us to distinguish **structural isomers**.
   - **Structural isomers** (aka constitutional isomers)**: Same** molecular formula, different structural formula (arrangements of atoms).

     Ex: C_4H_{10} has two isomers → TWO DIFFERENT COMPOUNDS!
3. **Condensed Formula:** Hybrid of molecular and structural formulae. Attempts to provide some structural information.
4. **Skeletal Formula:** Shows carbon backbone and any non-H atoms

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Isomers

Isomers: different compounds with same molecular formula

Stereoisomers: isomers where connections are same, but arrangement in space different

Constitutional Isomers: isomers where atoms are connected differently

Enantiomers: stereoisomers that are mirror images

Diastereomers: stereoisomers that are not mirror images

EXAMPLE: $C_2H_2Cl_2$ has 3 possible structures, only 2 are diastereomers

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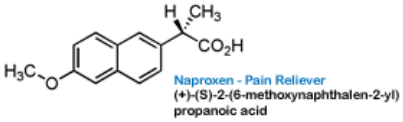
Enantiomers

Molecules that have Enantiomers are Chiral

- Amino Acids are one Enantiomer
- Some bacteria use the amino acids of the other chirality to trick their hosts

Enantiomers have similar physical properties (nearly identical)

- Interact differently with polarized light
- May have dramatically different reactivity
  - Naproxen: (*S*)-(+)-naproxen is used to treat arthritis pain, but (*R*)-(–)-naproxen causes liver poisoning with no analgesic effect.



Naproxen - Pain Reliever
(+)-(S)-2-(6-methoxynaphthalen-2-yl)
propanoic acid

Harmful Stereoisomer
(-)-(R)-2-(6-methoxynaphthalen-2-yl)
propanoic acid