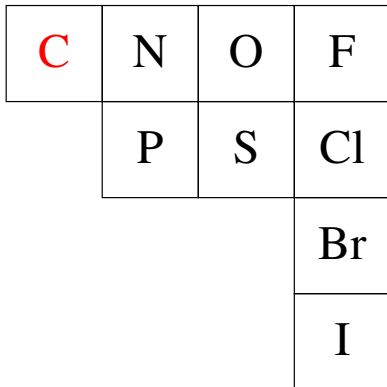
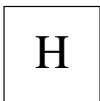


Chemistry 2000 Slide Set 17:
Introduction to organic chemistry

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March 14, 2020

The organic chemist's periodic table

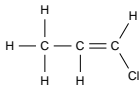


The chemistry of carbon

- Carbon almost universally adopts a complete octet by forming four two-electron bonds.
- Carbon can form single, double or triple bonds both to itself and to other elements.
- Possible (unstrained) bonding geometries:
 - Tetrahedral: four single bonds
 - Trigonal planar: one double bond and two single bonds
 - Linear: two double bonds *or* one triple bond and one single bond

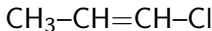
Structural diagrams

- We can draw a (more or less) complete Lewis diagram:



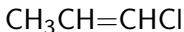
1-chloropropene

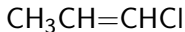
- Carbon-hydrogen bonds are often unchanged in organic reactions, so we often think in terms of CH_n groups:



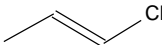
This is a **condensed structure**.

- Most bonds are single bonds, so we often leave those out too, giving us a **condensed structural formula**:





- Most organic compounds are mostly made of carbon and hydrogen.
- As noted above, the hydrogens often don't participate in reactions.
- We can simply draw lines for the bonds between carbon atoms, leaving out the carbon atoms themselves, and leaving out the hydrogen atoms attached to carbon atoms altogether:



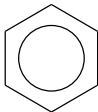
This is a **line-bond structure**.

- Carbon atoms are assumed to be found where two lines join or where a line ends.
Enough hydrogen atoms are assumed to be there to satisfy carbon's normal valence of 4.

Structural diagrams

Delocalized rings

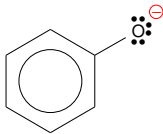
- Benzene (C_6H_6), and some other ring systems with delocalized π bonds, have a special representation as line-bond structures.
- Because the π bonds are delocalized over the ring, we do not draw double bonds between specific pairs of atoms.
- Instead, we draw a circle to represent the delocalized π electrons:



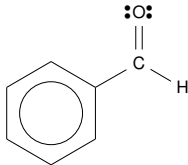
Structural diagrams

Lone pairs, charges, mixed structures

- Despite the highly simplified nature of line-bond structures, you should think of them as shorthand for a Lewis diagram.
- Important **lone pairs** and **all non-zero formal charges** should be placed on these diagrams.

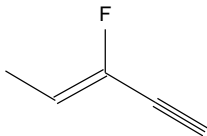
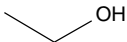


- When we want to emphasize a particular part of the structure, it is also possible to mix the line-bond and Lewis formalisms.




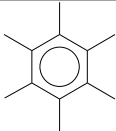

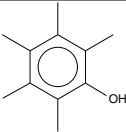

Exercise

For each of the following line-bond structures, draw a complete Lewis diagram.



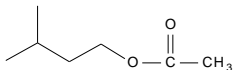
Functional groups

- Compounds with common structural features (bonding arrangements, common groupings of atoms) tend to react similarly.
- In organic chemistry, a structural feature found in many molecules is called a **functional group**.
- When describing functional groups, we often use R to represent an arbitrary carbon chain (or H).

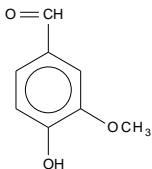
Structural feature	Functional group	Example
C-H compound with no other functional groups	alkane	CH_3CH_3
	alkene	$\text{CH}_2=\text{CH}_2$
$-\text{C}\equiv\text{C}-$	alkyne	$\text{CH}\equiv\text{CH}$
	arene	
$-\text{OH}$	alcohol	CH_3OH
	phenol	
$\text{R}_1-\text{O}-\text{R}_2$	ether	$\text{CH}_3-\text{O}-\text{CH}_3$

Exercise: Find the functional groups

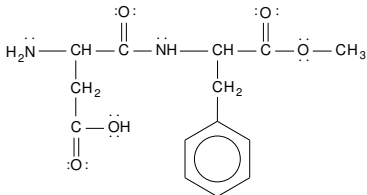
Isoamyl acetate: (artificial banana flavor)



Vanillin:



Aspartame:



(methyl ester of the aspartic acid-phenylalanine dipeptide)

Isomerism

Isomers are compounds with the same chemical formula (same atoms), but arranged differently.

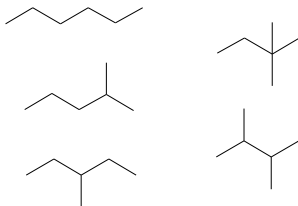
Structural isomers differ in what is bonded to what.

Stereoisomers have identical chemical bonds, but are arranged differently in space.

Structural isomerism

- Organic compounds typically have many structural isomers, particularly so for larger compounds with many atoms.
- Structural isomers have different physical properties (melting points, etc.).

Example: Structural isomers of hexane (C_6H_{14}):



Exercise

Draw as many structural isomers for the formula C_5H_{10} as you can think of.

Some types of stereoisomerism

Geometrical isomers have identical bonds, but the distances between some nonbonded atoms are different due to a different arrangement of the bonds in space.

- In compounds with rings to which two substituents are attached, the two substituents can be on the same side of the ring (say, both up) or on opposite sides (one up, one down).

Both on the same side: **cis**

Substituents on opposite sides: **trans**

Example: The compound  has two geometrical isomers:



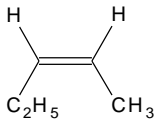
cis



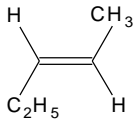
trans

- Due to the rigidity of the π bond, molecules with double bonds also have cis and trans isomers.

Example:



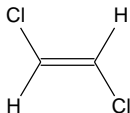
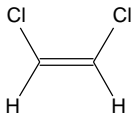
cis



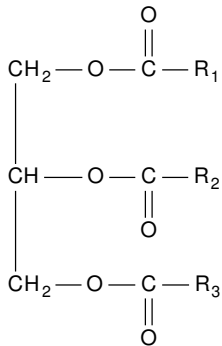
trans

- Geometrical isomers generally have different physical and chemical properties.

Example: Which one of the following isomers has a higher boiling point?



Example: Fats have the general formula

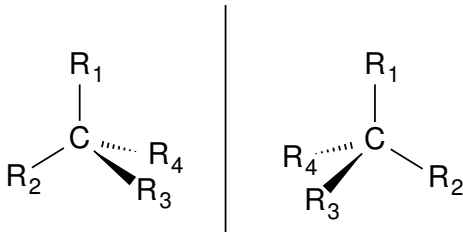


- Fats whose R groups contain double bonds are said to be unsaturated.
- Natural fats always have cis double-bond geometries.
- Trans fats pack together better, so they tend to be deposited in arteries.

Enantiomers are non-superimposable mirror images (like your hands).

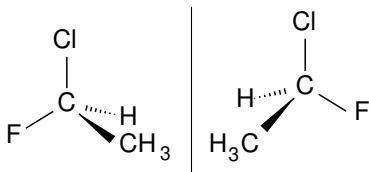
- A compound that has an enantiomer is said to be **chiral**.
- Enantiomerism is also known as optical isomerism because chiral molecules rotate plane-polarized light.
- In organic chemistry, enantiomerism arises most often when a molecule contains one (or more) carbon atoms attached to four non-equivalent groups.

Such a carbon atom is called a **chirality centre**.

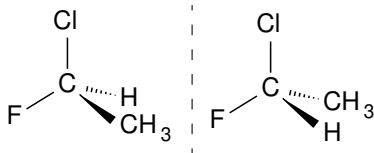


Checking whether a molecule is chiral

- Draw mirror image:



- Rotate the mirror image to place it in as similar a position to the original as possible, then compare:

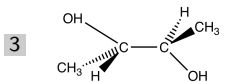
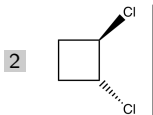
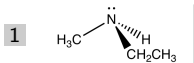


Checking whether a molecule is chiral

- Note that the ultimate criterion for chirality is whether a molecule and its mirror image can be superimposed, **not** the presence of a chirality centre.

Some exercises

Which of the following are chiral?



- Enantiomers have identical physical properties and reactivity **unless** reacting with another chiral agent.
- Amino acids (and thus enzymes) are chiral.
- Enzymes can therefore carry out stereo-specific reactions, which is very hard to do with ordinary chemical reagents.