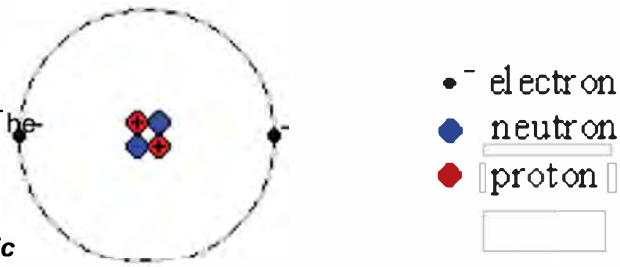
Organic Chemistry 1 Complete Lecture + Textbook Notes

Atoms

All matter is composed of **atoms**. Atoms are an ordered collection of various *sub*atomic particles. The central *nucleus* contains the *protons* and *neutrons*, around this are the all important *electrons*.

The simple schematic diagram to the left shows this simple model of a helium atom. The nucleus contains two protons and two neutrons, and then there are two electrons.



You should be familiar with the subatomic particles and how to determine how many of each a specific atom has.

In introductory organic chemistry courses, the majority of the compounds you will encounter are based on a limited selection of atoms : the atoms of greatest interest are **H**, **C**, **N**, **O**, and the halogens **F**, **Cl**, **Br**, **I** plus a few others such as Li, Na, Mg, Al, B, P, S. Later, when one probes deeper into more advanced synthetic methods, one needs to be familiar with many more elements.

Electrons and Orbtials

The electron is the subatomic particle that is fundamental to chemical bonding.

Simply put, chemical reactions are about reorganising bonds
And bonds are due electrons
So that means chemistry is all about electrons.

Study Tip:
Learn to keep track of electrons ! Pay attention to charges.
You will find that if you know where the electrons are and what they are doing, then it is much easier to master organic chemistry.

Electrons have always been thought of as **particles** since their discovery in 1897.
But in 1924 it was also suggested that electrons also have **wave** like properties.
This is the concept of "wave-particle duality" due to De Broglie.

Functional Groups

- A **functional group** is an atom or a group of atoms within a molecule, that prescribes a particular type of reactivity when subjected to a particular set of reaction conditions.

As organic chemistry unfolds, take notice that the reactions occur directly at or immediately adjacent to the functional groups, and that recognizing the functional groups is the key to recognizing the type of reaction.

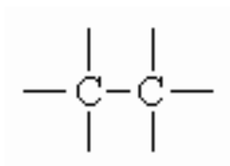
What is a reaction ?

- A reaction is the process by which one compound is transformed into a new compound.

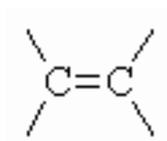
List of Functional Groups

The more important functional groups are shown below, with the key structural element and a 3D CHIME image of a simple example. It is important that you are able to recognize these functional groups because they are the key to being able to recognize the patterns within organic chemistry.

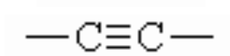
Alkane



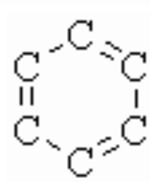
Alkene



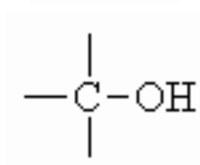
Alkyne



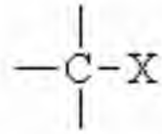
Arene



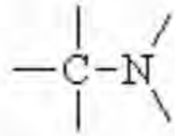
Alcohol



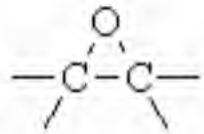
Alkyl halide



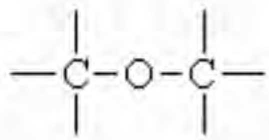
Amine



Epoxide



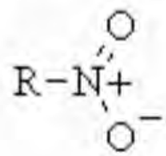
Ether



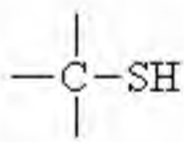
Nitrile

$R-C\equiv N$

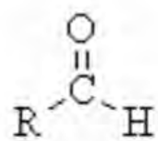
Nitroalkane



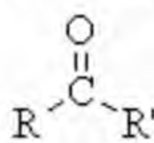
Thiol



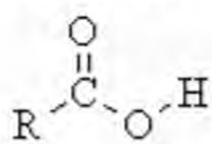
Aldehyde

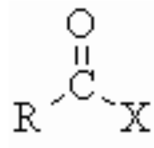


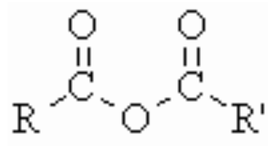
Ketone

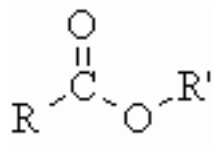


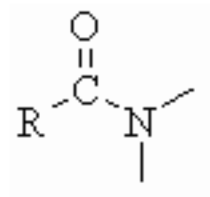
Carboxylic Acid



Acyl halide 

Acid anhydride 

Ester 

Amide 

Hydrocarbons are compounds that *only* contain H and C atoms, but they can be subdivided according to the following tree diagram depending on the bond types that are present.

Hydrocarbons
C_cH_h

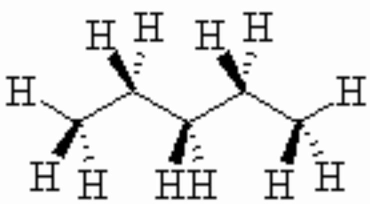
Alkanes	**Alkenes**	**Alkynes**	**Arenes**
Only CC s bonds all C sp^3 hybridized	CC s and p bonds C=C	CC s and 2p bonds C≡C	6 C cyclic array with alternate s and p bonds

Simplest organic molecules with only C and H atoms. Commercially important as fuels and oils.

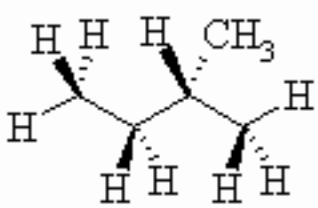
Nomenclature:
Functional group suffix = -ane
Functional group prefix = alkyl-

Physical Properties:
The low polarity of all the bonds in alkanes means that the only intermolecular forces between molecules of alkanes are the very weak induced dipole - induced dipole forces, which are easily overcome. As a result, compared to other functional groups, alkanes tend to have low melting and boiling points and very low solubility in polar solvents such as water (remember "oil and water don't mix" and the adage "like dissolves like").

Note: the molecular polarities of all hydrocarbons are assumed to be essentially zero, due to the small electronegativity difference between H and C.



All bond polarities in this molecule cancel so that the overall dipole moment of this molecule is zero

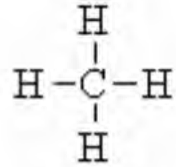


Even though you might expect a resultant vector, from the sum of all bondpolarities, the number is so small, one can assume a net dipole moment of zero for this hydrocarbon

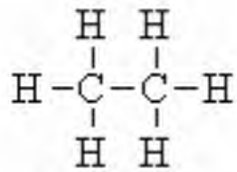
Structure:
Alkanes are the simplest organic compounds, comprised of only sp^3 hybridized C and H atoms connected by s bonds.
They have a generic formula of C_nH_{2n+2} (a relationship that also defines the maximum number of hydrogen atoms that can be present for a given number of C atoms).
Structures of the simple C1 to C4 alkanes are shown below in a variety of

representations. As the number of C atoms increases then other isomeric structures are possible

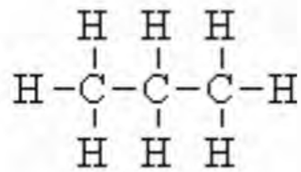
Methane
CH_4
(b.pt. = -160°C)



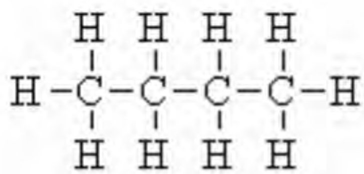
Ethane
C_2H_6
(b.pt. = -89°C)



Propane
C_3H_8
(b.pt. = -42°C)

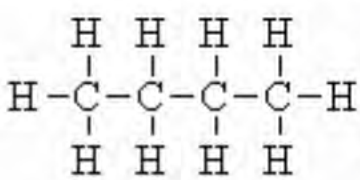


Butane
C_4H_{10}
(b.pt. = -0.4°C)



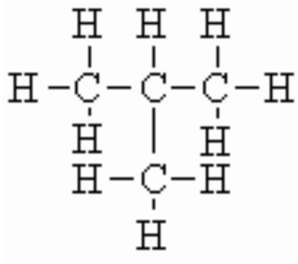
Isomeric Alkanes:
The molecular formula for the C1 to C3 alkanes lead to single, unique structures. However for C_4H_{10}, there are two possible constitutional isomers. It is important to be able to recognize isomers because there can have different chemical, physical properties and biological properties. The constitutional isomers of C_4H_{10} are shown below along with some properties:

n-butane



m.pt.= -139°C
b.pt. = -0.4°C
ΔH_f = -125.6 kJ/mol
(-30.0 kcal/mol)
ΔH_c = -2877 kJ/mol
(-687 kcal/mol)

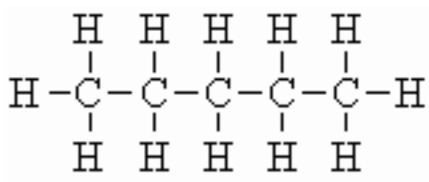
isobutane



m.pt.= -161°C
b.pt. = -10.2°C
ΔH_f = -135.6 kJ/mol
(-32.4 kcal/mol)
ΔH_c =-2868 kJ/mol
(-685 kcal/mol)

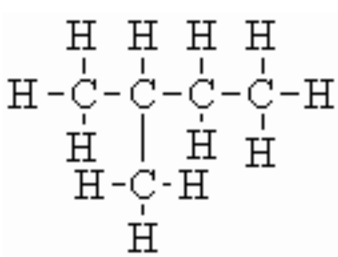
C_5H_{12} has three possible constitutional isomers:

n-pentane



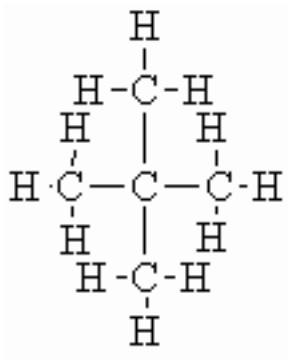
b.pt. = 36.1 °C
ΔH_f = -147 kJ/mol
(-35.1 kcal/mol)
ΔH_c = -3509 kJ/mol
(-839 kcal/mol)

isopentane



b.pt. = 30 °C
ΔH_f = -154.1 kJ/mol
(-36.8 kcal/mol)
ΔH_c = -3502 kJ/mol
(-837 kcal/mol)

neopentane



b.pt. = 9.5 °C
ΔH_c = -3493 kJ/mol
ΔH_f = -168.0 kJ/mol (-40.1 kcal/mol)
ΔH_c = -3493 kJ/mol (-835 kcal/mol)

Stability:

- Branched alkanes are more stable than linear alkanes, *e.g.* 2-methylpropane is more stable than n-butane.

Reactivity:

- Since C and H atoms have very similar electronegativities, so all the bonds in alkanes (C-C and C-H) are non-polar.
- As a result, alkanes are not particularly reactive as functional groups go.
- In fact, it is often convenient to regard the hydrocarbon framework of a molecule as an unreactive support for the more reactive functional groups.

Another type of molecule containing only sp^3 hybridized C and H atoms connected by s bonds is possible with a ring of 3 or more C atoms. These are the **cycloalkanes** which are fairly common in the world of organic chemistry, both man-made and natural.

Nomenclature:
Functional group prefix = cyclo-

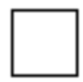
Physical Properties:
Like alkanes, the low polarity of all the bonds in cycloalkanes means that the only intermolecular forces between molecules of cycloalkanes are the very weak

induced dipole - induced dipole forces, also known as **london forces** which are easily overcome. As a result, compared to other functional groups, but like alkanes, cycloakanes tend to have low melting and boiling points.

Structure:
They have a generic formula of C_nH_{2n}, (note: there 2 less H atoms compared to the analogous alkane).
The C3 to C6 cycloalkanes are shown below in a variety of representations.

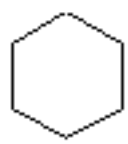
Cyclopropane
C_3H_6

Cyclobutane
C_4H_8



Cyclopentane
C_5H_{10}

Cyclohexane
C_6H_{12}

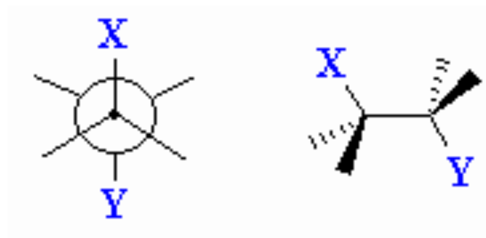
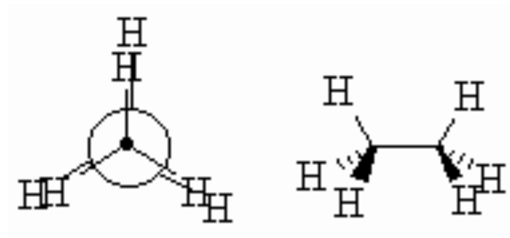
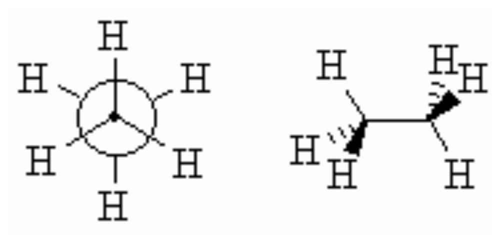
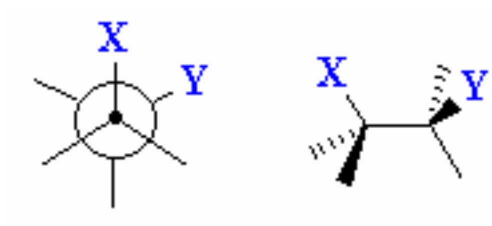
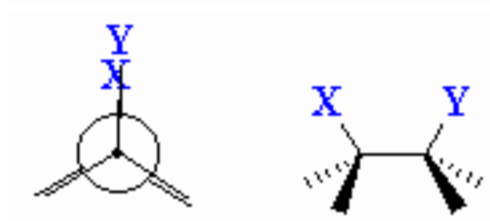


Reactivity:

- Very similar reactivity to the closely related alkanes which have the same types of bonds.
- Since C and H atoms have very similar electronegativities, both the C-H and C-C bonds are non-polar.
- As a result, cycloalkanes, like alkanes, are not a very reactive functional group

Conformational Language

An alphabetical list of key terms in the language of conformational analysis is provided below, linked to the more detailed descriptions within the chapter pages

Anti	Description given to two substitutents attached to adjacent atoms when their bonds are at 180^{o} with respect to each other	
Eclipsed	A high energy conformation where the bonds on adjacent atoms are aligned with each other	
Staggered	A low energy conformation where the bonds on adjacent atoms bisect each other, maximizing the separation	
Gauche	Description given to two substitutents attached to adjacent atoms when their bonds are at 60^{o} with respect to each other	
Syn	Description given to two substitutents attached to adjacent atoms when their bonds are at 0^{o} with respect to each other	
Conformations	Different spatial arrangments that a molecule can adopt due to rotation about sigma bonds	
Conformers	Contracted version of	