Week 10 Compounds of carbon

Bonding in carbon compounds

- Carbon is a small atom with 4 outer-shell electrons.
- The carbon atoms forms covalent bonds by sharing these electrons with other atoms.
- Carbon forms strong covalent bonds with other carbon atoms (single; double; triple bonds), hydrogen, oxygen, nitrogen, sulfur, phosphorus and the halogens.

When 4 single bonds are formed around a carbon atom, the charge cloud of the electron pairs in each bond repel each other.

The bonds are then spread out as far apart as possible resulting in a tetrahedral distribution.

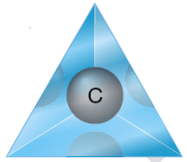


Figure 9.3
A tetrahedron has four triangular faces. The electrons in four single bonds around a carbon atom repel so that the bonds point to the corners of a tetrahedron. In this arrangement the angle between the bonds is 109.5°.

Molecules of long chains of carbon atoms joined by single bonds are often referred to as “straight chain molecules” but in fact, due to the tetrahedral distribution of the bonding pairs, the chain is bent.

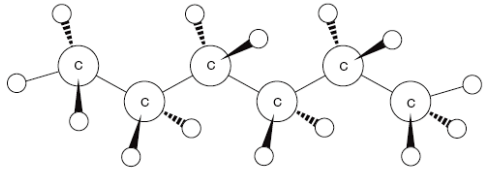


Figure 9.4
Tetrahedral arrangement in a carbon chain.

Homologous series

Where the compounds have similar structures and chemical properties and general formula. Each member of a homologous series differs by a –CH2- group from the previous member. There is a gradation in physical properties as a result of increase in molecular size and mass.

No. of carbons	1	2	3	4	5	6	7	8	9	10
Prefix	Meth	Eth	Prop	But	Pent	Hex	Hept	Oct	Non	Dec

11	12	13	14	15	20	30
Undec	Dodec	Tridec	Tetradec	Pentadec	Eicos	Triacont

Alkanes

The simplest series
C_nH_{2n+2}

- are saturated hydrocarbons because they do not react further with hydrogen.
- only single carbon-carbon bonds are present.

TABLE 9.1 The alkane homologous series, general formula C_nH_{2n+2}

n	Name	Formula
1	Methane	CH_4
2	Ethane	C_2H_6
3	Propane	C_3H_8
4	Butane	C_4H_{10}
5	Pentane	C_5H_{12}
6	Hexane	C_6H_{14}
7	Heptane	C_7H_{16}
8	Octane	C_8H_{18}
9	Nonane	C_9H_{20}
10	Decane	$C_{10}H_{22}$

Butane

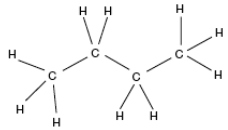


Figure 9.5
Structural formula of butane.

CH_3-CH_2-CH_2-CH_3 or

$CH_3CH_2CH_2CH3$ or

$CH_3(CH_2)_2CH_3$

Semi-structural formula

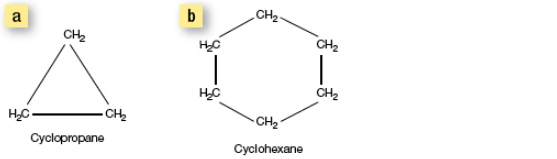


Figure 9.6
a Cyclopropane, C_3H_6, and **b** cyclohexane, C_6H_{12}, are examples of cyclic molecules.

- Alkanes with less than 4 carbon atoms per molecule have only one possible structure.
- From butane onwards there are progressively more molecules that have different atomic arrangements but the same molecular formula.
- Molecules having the same molecular formula but different structural formulas are known as **structural isomers**.

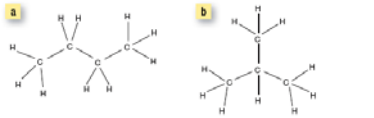


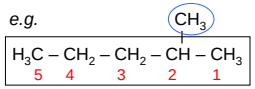
Figure 9.8
Structural isomers of butane: **a** butane **b** methylpropane.

As the molecules get larger, the degree of isomerism increases rapidly. 75 structural isomers for decane compared to 350,000 for $C_{20}H_{42}$.

Systematic naming of alkanes

Usually contains a prefix, a stem and a suffix.

e.g.



1. Identify the longest chain of carbon atoms. The longest chain has 5 carbons (parent hydrocarbon) and so the stem must be *pent*.
2. Since all the bonds are single, the compound must be an alkane and the name will end in *ane*.
3. Identify the side chain.
4. Number the carbons in the longest chain such that the side chain is attached to the lowest numbered carbon.
5. A methyl group is attached to the second carbon thus the prefix will be *2-methyl*.

The name of the hydrocarbon is 2-*methylpentane*.

Alkenes

Hydrocarbons with double covalent bonds between carbon atoms.
Are unsaturated hydrocarbons.
C_nH_{2n} names end in *ene*.

- Alkenes are more reactive than alkanes because of the additional density of electrons held in bonds between the carbon atoms.
- Shape around the double bond is planar (angle of 120°)
- There are still tetrahedral orientations for those carbons not involved in double bonds.

Table 9.3 The alkene homologous series, general formula C_nH_{2n}

n	Name	Formula
1	–	–
2	Ethene	C_2H_4
3	Propene	C_3H_6
4	Butene	C_4H_8
5	Pentene	C_5H_{10}
6	Hexene	C_6H_{12}
7	Heptene	C_7H_{14}
8	Octene	C_8H_{16}
9	Nonene	C_9H_{18}
10	Decene	$C_{10}H_{20}$

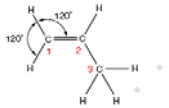


Figure 9.13
Structural formula of propene. The bonds around carbon atoms 1 and 2 are planar while the bonds around carbon atom 3 are arranged tetrahedrally.

Systematic naming of alkenes

1. Based on the longest chain containing the double bond.
2. Position of the double bond is indicated by the first carbon atom involved in the double bond.
3. Numbering of the carbons starts from the end nearest the double bond.
4. The rules for naming any side chains is the same as those for alkanes.

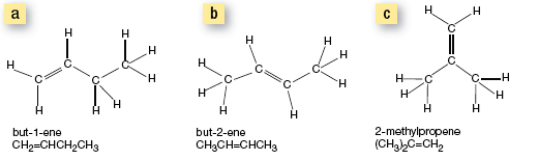


Figure 9.14
Isomers of butene: **a** but-1-ene, **b** but-2-ene, **c** 2-methylpropene

key questions

1 Give the meaning of the following terms:
- **a** homologous series
- **b** structural isomers
- **c** structural formula
- **d** semi-structural formula
- **e** saturated
- **f** unsaturated

2 Identify the homologous series to which each of the following belongs:
- **a** C_3H_8
- **b** C_2H_4
- **c** C_5H_{10}
- **d** C_6H_{18}
- **e** $CH_3(CH_2)_5CH_3$
- **f** $CH_3CH=CHCH_2CH_3$

3 Draw the structural formula of:
- **a** ethane
- **b** propene
- **c** butane
- **d** methylbutane
- **e** 3-ethyloctane
- **f** 2,3-dimethylhexane

4 Explain why there is only one compound corresponding to the formula C_3H_8 while there are over 70 compounds corresponding to the molecular formula $C_{10}H_{22}$.