12 La chimica del carbonio

Summing-up

The name **organic chemistry** is used to denote the chemical compounds consisting of carbon in combination with other elements (hydrogen, nitrogen, oxygen, sulfur and phosphorus). Carbon, which is located in group IV of the periodic table, has four valence electrons (tetravalent) and hence, by binding with other atoms, forms four covalent bonds.

Hydrocarbons are binary compounds, which consist of only two elements, namely carbon and hydrogen. They are described as **saturated hydrocarbons** when each carbon atom bonds binds with four other atoms, forming only single bonds. There hydrocarbons are identified by the same molecular formula but characterised by a different arrangement of atoms in the molecule: such compounds are called **isomers**.

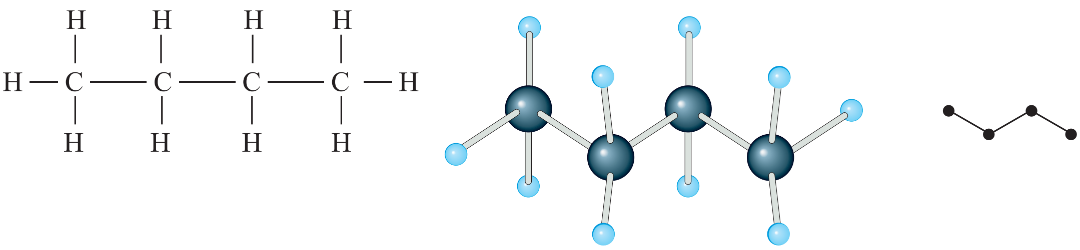
Alkanes are saturated hydrocarbons, with open-chain, linear or branched structure, whose name, according to the rules of nomenclature, end with the suffix -*ane*.

The **cycloalkanes** are always saturated but close chained.

The molecules of alkanes and cycloalkanes are nonpolar because, although the covalent C—H bond is polarised, the tetrahedral structure of each carbon atom leads to an overall symmetric charge distribution in the molecules. It follows that the hydrocarbons are nonpolar compounds, and are practically insoluble in water (a polar substance). The melting and boiling points of linear chain alkanes depend on the intensity of London dispersion forces and therefore increases with the number of carbon atoms that form the chain.

Four different conventions are used to represent the hydrocarbons:

- the molecular formula is known as the *empirical* or *raw formula* and is obviously the least informative as it details only the ratios between the atoms in the molecule (for example, the empirical formula for butane is C_4H_{10});
- the *structural formula* is the most informative, as it describes all the atoms with their bonds represented by a dash;
- the *condensed formula,* in which only the C—C bonds are represented with a hyphen;
- the *simplified formula,* in which only the molecular skeleton formed by the carbon atoms, which are marked with an enlarged point, is included.



Unsaturated hydrocarbons are made up of molecules in which at least one carbon atom is linked with less than four atoms. The **alkenes** are hydrocarbons, with open-chain structure, with a double bond between two carbon atoms and whose name ends with the suffix -*ene*. The **alkynes** are open-chain hydrocarbons with a triple bond between two carbon atoms and whose name ends with the suffix -*yne*. Saturated or unsaturated hydrocarbons, both open chain or cyclic, are known as aliphatic hydrocarbons.

As with aliphatic hydrocarbons, **aromatic hydrocarbons** are found in petroleum; these are compounds that have a characteristic chemical behaviour due to the presence of one or more benzene rings, that is, a cyclic structure in which the bond between the carbon atoms is interpreted with the theory of electron delocalisation. The term *electron delocalisation* is used to indicate a model of molecular structure in which the charge of the covalent bonding electrons is shared between more than two atoms, creating a form of current through the skeleton of the molecule.

The reactions that can modify a molecule of a hydrocarbon are classified into two main categories:

- *substitution reactions* are reactions involving the replacement of one or more hydrogen atoms with one or more different atoms (or different groups of atoms);
- *addition reactions* are reactions in which two atoms (or groups of atoms) bind to the carbon atoms with double or triple bonds.

All hydrocarbons can be involved in combustion reactions and substitution reactions while only unsaturated hydrocarbons can also give rise to addition reactions.

In general we can say that, under the same conditions, unsaturated hydrocarbons have a greater tendency to react than saturated hydrocarbons. Aromatic hydrocarbons primarily react via the substitution reaction.

In addition the hydrocarbons, organic chemistry includes several other compounds characterised by the presence of atoms or groups of atoms, other than carbon and hydrogen, in their molecules.

In general, an atom or group of atoms within a molecule that characterises a compound as belonging to a class of compounds is called a **functional group**. The presence of a functional group imparts physical and chemical properties to a substance that are entirely different from those of a hydrocarbon.

We define **functional isomers** of compounds as those that have the same empirical formula but belong to different classes. For example, aldehydes and ketones are functional isomers.

Halogenated hydrocarbons (or *halohydrocarbons*) are compounds that have one or more atoms of an element belonging to the group of halogens attached to one or more carbon atoms of an aliphatic (generally represented by the letter R) or aromatic (Ar) chain.

Alcohols are compounds that have the hydroxyl functional group —OH attached to an aliphatic chain. As this functional group contains a strongly polarised bond, strong intermolecular forces exist between the alcohol molecules that are more intense than those between the apolar hydrocarbon molecules.

The influence of a functional group decreases as the length of the hydrocarbon chain increases. Depending on how many carbon atoms are linked to the carbon atom to which the hydroxyl group is attached, alcohols can be classified into *primary, secondary* and *tertiary alcohols*. The different position of the hydroxyl group is important because it affects both the physical and chemical behaviour of an alcohol.

The **ethers** are compounds that can be obtained from the *condensation reaction* between two alcohol molecules; in general, in a condensation reaction two molecules combine into one, releasing a molecule of water at the same time.

The **aldehydes** and **ketones** are families of compounds characterised by the presence of the carbonyl functional group $>C{=}O$.

Carboxylic acids are compounds characterised by the presence of the carboxylic acid functional group —COOH; in water the carboxylic acids show a marked acidic character, especially if the carboxyl group is linked to a chain consisting of a few atoms of carbon.

Esters are compounds that can be obtained from the *condensation reaction* between an alcohol molecule and a carboxylic acid.

Amines are compounds that have a nitrogen atom linked to one, two or three carbon atoms belonging to aliphatic or aromatic chains. Depending on how many carbon atoms are bound to the nitrogen, amines are classified as primary, secondary or tertiary. Since the nitrogen atom has a lone electron pair the amines generally show basic character.

Amides are compounds that contain both nitrogen and oxygen in the same amide functional group.

Heterocyclic compounds are cyclic compounds in whose rings other elements, in addition to carbon atoms, are present.