

3.1.2

Isomers

How atoms are placed within organic molecules (three-dimensional structure/chemical bonds) determines the overall function of the molecule. Interestingly, some molecules can have the exact same number and types of atoms (i.e., chemical formula) but those atoms can be arranged completely differently, dramatically changing function. In this case, we called these molecules **isomers**. There are two types of isomers: **structural isomers** and **stereoisomers**. Stereoisomers can be further subdivided into **geometric isomers**, **enantiomers** and **diastereomers**.

Structural Isomerism

Structural isomers, also called *constitutional isomers*, have the same molecular formula but with different arrangements of atoms. For example, butane and isobutene both contain four carbons and ten hydrogens (C_4H_{10}) but because of their structural differences, butane is an explosive fuel property and isobutane is a propellant (“cold” properties) used as a refrigerant. We call them structural isomers because they have a different pattern of covalent bonding. In butane all the carbons form a single chain, but the carbons in isobutene form a branched chain.

Stereoisomers

Stereoisomers have the same number of atoms and bonds, but they differ in how their atoms are oriented around one or more carbons. Often, they look very similar, but if you were to try and stack them on top of each other they would not fit, a phenomenon that is called non-super imposable structures.

Geometric isomers

Geometric isomers also have the same molecular formula and the same pattern of covalent bonding but differ in how atoms are spaced around a double covalent bond, especially in a carbon-to-carbon double bond. For example, consider the molecule butene (C_4H_8). In the molecule butene the two methyl groups (CH_3) can be located on same side as the double bond (**cis configuration**) or opposite sides (**trans configuration**). The cis arrangement makes the molecule bend since the two methyl groups act to “repel” each other, whereas in the trans configuration the molecule will be more linear as the two methyl groups “balance” each other.

Enantiomers

When two molecules’ atoms are arranged in the exact opposite way, so that they actually look the same in the mirror, we call them enantiomers. To be an enantiomer the atoms swap positions around a central carbon called an **asymmetric carbon**. At this point you may be thinking: “How on earth did anyone in the right mind figure this stuff out when they can’t even see them!?” Well, in the case of enantiomers scientists used the properties of light. Apparently, when you shine light at structures that are invisible to the naked eye, light rotates, and rotating light is something that can be seen. Thus, even though a molecule has the same molecular formula, swapping positions with different groups of atoms to create a mirror image can drastically affect how light rotates through it. The term mirror image refers to the result of the swapping groups of atoms (**functional groups; see below**) around a center carbon and can be captured in one concept

called **chirality**. For example, a metal rod would not be considered chiral because its appearance in a mirror would look the same. However, consider the threads on a screw. Rotating the threads to the right would appear as if you were rotating the screw to the left in the mirror, this effect could be described as chiral.

In chemistry, a chiral molecule can exist in two forms, described as non-superimposable mirror images, and these two forms are called enantiomers. Non-superimposable mean that if you tried to stack images of the two molecules on top of each other they would not line up. Consider your hands, they are mirror images of each other but they do not stack on top of each other. Pairs of enantiomers will rotate light either clockwise (to the right) or counterclockwise (to the left). Initially, clockwise rotations (right) were described as dextrorotary (d) and counterclockwise rotation (left) as levorotary (l). This nomenclature evolved to the capital D and capital L system. Once a structure has been identified, determining which way light will rotate is determined using the Cahn-Ingold-Prelog (CIP) system which uses R (clockwise) and S (counterclockwise) nomenclature. The CIP system assigns priority based on atomic numbers to help determine the rotation ($I > Br > Cl > S > P > F > O > N > C > H$).

Diastereomers

The final group of stereoisomers are diastereomers which are very similar to enantiomers except that they contain more than one asymmetric carbon. This property makes it impossible for them to form mirror images.



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