Objectives

After completing this section, you should be able to

1. draw the Kekulé structure, condensed structure and shorthand structure of each of the first ten straight-chain alkanes.
2. name each of the first ten straight-chain alkanes, given its molecular formula, Kekulé structure, condensed structure or shorthand structure.
3. explain the difference in structure between a straight- and a branched-chain alkane, and illustrate the difference using a suitable example.
4. explain why the number of possible isomers for a given molecular formula increases as the number of carbon atoms increases.
5. draw all the possible isomers that correspond to a given molecular formula of the type \(C_nH_{2n+2}\), where \(n\) is \(\leq 7\).

Key Terms

Make certain that you can define, and use in context, the key terms below.

- branched-chain alkane
- constitutional or structural isomer
- homologous series
- isomer
- saturated hydrocarbon
- straight-chain alkane (or normal alkane)

Study Notes

A series of compounds in which successive members differ from one another by a CH\(_2\) unit is called a homologous series. Thus, the series CH\(_4\), C\(_2\)H\(_6\), C\(_3\)H\(_8\) . . . C\(_n\)H\(_{2n+2}\), is an example of a homologous series.

It is important that you commit to memory the names of the first 10 straight-chain alkanes (i.e., from CH\(_4\) to C\(_{10}\)H\(_{22}\)). You will use these names repeatedly when you begin to learn how to derive the systematic names of a large variety of organic compounds. You need not remember the number of isomers possible for alkanes containing more than seven carbon atoms. Such information is available in reference books when it is needed. When drawing isomers, be careful not to deceive yourself into thinking that you can draw more isomers than you are supposed to be able to. Remember that it is possible to draw each isomer in several different ways and you may inadvertently count the same isomer more than once.

Alkanes are organic compounds that consist entirely of single-bonded carbon and hydrogen atoms and lack any other functional groups. Alkanes can be subdivided into the following three groups: the straight-chain alkanes, branched alkanes, and cycloalkanes. Alkanes and branched alkanes have the general formula \(C_nH_{2n+2}\). Alkanes are sometimes called saturated hydrocarbons, meaning that all of the carbons atoms that make up the molecule are single bonded to other atoms (no double or triple bonds).
Cycloalkanes are cyclic hydrocarbons, meaning that some or all of the carbons in the molecule are arranged in the form of a ring. Cycloalkanes have the general formula \((C_nH_{2n})\). Cycloalkanes are also saturated. There are also polycyclic alkanes, which are molecules that contain two or more cycloalkanes that are joined, forming multiple rings.

This is an introductory page about alkanes, such as methane, ethane, propane, butane and the remainder of the common alkanes. This page addresses their formula and isomerism, their physical properties, and an introduction to their chemical reactivity.

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**Molecular Formulas**

Alkanes are the simplest family of hydrocarbons - compounds containing carbon and hydrogen only. Alkanes only contain carbon-hydrogen bonds and carbon-carbon single bonds. The first six alkanes are as follows:

- methane: \(\text{CH}_4\)
- ethane: \(\text{C}_2\text{H}_6\)
- propane: \(\text{C}_3\text{H}_8\)
- butane: \(\text{C}_4\text{H}_{10}\)
- pentane: \(\text{C}_5\text{H}_{12}\)
- hexane: \(\text{C}_6\text{H}_{14}\)

You can work out the formula of any of the alkanes using the general formula \(\text{C}_n\text{H}_{2n+2}\).

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**Isomerism**

All of the alkanes containing 4 or more carbon atoms show structural isomerism, meaning that there are two or more different structural formulae that you can draw for each molecular formula.

Example: Butane or MethylPropane

\(\text{C}_4\text{H}_{10}\) could be either of these two different molecules:

- **Butane**
  - \(\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_3\)
- **MethylPropane**
  - \(\text{CH}_3-\text{CH}_2-\text{CH}_3\)
  - \(\text{CH}_3-\text{CH}-\text{CH}_3\)

These are named butane and 2-methylpropane, respectively.
What is structural isomerism?

Isomers are molecules that have the same molecular formula, but have a different arrangement of the atoms in space. That excludes any different arrangements which are simply due to the molecule rotating as a whole, or rotating about particular bonds. For example, both of the following are the same molecule. They are not isomers; both are butane.

There are also endless other possible ways that this molecule could twist itself. There is completely free rotation around all the carbon-carbon single bonds. If you had a model of a molecule in front of you, you would have to take it to pieces and rebuild it if you wanted to make an isomer of that molecule. If you can make an apparently different molecule just by rotating single bonds, it's not different - it's still the same molecule.

In structural isomerism, the atoms are arranged in a completely different order. This is easier to see with specific examples. What follows looks at some of the ways that structural isomers can arise. The names of the various forms of structural isomerism probably do not matter all that much, but you must be aware of the different possibilities when you come to draw isomers.

Chain isomerism

These isomers arise because of the possibility of branching in carbon chains. For example, there are two isomers of butane, C₄H₁₀. In one of them, the carbon atoms lie in a "straight chain" whereas in the other the chain is branched.

Be careful not to draw "false" isomers which are just twisted versions of the original molecule. For example, this structure is just the straight chain version of butane rotated about the central carbon-carbon bond.
You could easily see this with a model. This is the example we’ve already used at the top of this page.

Example \(\PageIndex{1}\): Chain Isomers in Pentane

Pentane, \(C_5H_{12}\), has three chain isomers. If you think you can find any others, they are simply twisted versions of the ones below. If in doubt make some models.

Exercises

Questions

Q3.2.1

Give all the isomers for a straight chain hexanol.

Solutions

S3.2.1
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