Objectives

After completing this section, you should be able to

1. recognize and name any alkyl group that can be considered to have been formed by the removal of a terminal hydrogen atom from a straight-chain alkane containing ten or fewer carbon atoms.
2. explain what is meant by a primary, secondary, tertiary or quaternary carbon atom.
3. represent the various types of organic compounds using the symbol "R" to represent any alkyl group.

Key Terms

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

- alkyl group
- methyl group
- isopropyl group
- sec-butyl group
- isobutyl group
- tert-butyl group
- primary carbon
- secondary carbon
- tertiary carbon
- quaternary carbon

Study Notes

The differences among primary, secondary, tertiary and quaternary carbon atoms are explained in the following discussion. A convenient way of memorizing this classification scheme is to remember that a primary carbon atom is attached directly to only one other carbon atom, a secondary carbon atom is attached directly to two carbon atoms, and so on.

The IUPAC system requires first that we have names for simple unbranched chains, as noted above, and second that we have names for simple alkyl groups that may be attached to the chains. Examples of some common alkyl groups are given in the following table. Note that the "ane" suffix is replaced by "yl" in naming groups. The symbol R is used to designate a generic (unspecified) alkyl group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃−</td>
<td>Methyl</td>
</tr>
<tr>
<td>C₂H₅−</td>
<td>Ethyl</td>
</tr>
<tr>
<td>CH₃CH₂CH₂−</td>
<td>Propyl</td>
</tr>
<tr>
<td>(CH₃)₂CH−</td>
<td>Isopropyl</td>
</tr>
<tr>
<td>CH₃CH₂CH₂CH₂−</td>
<td>Butyl</td>
</tr>
<tr>
<td>(CH₃)₂CHCH₂−</td>
<td>Isobutyl</td>
</tr>
<tr>
<td>CH₃CH₂CH(CH₃)−</td>
<td>sec-Butyl</td>
</tr>
<tr>
<td>(CH₃)₃CH−</td>
<td>tert-Butyl</td>
</tr>
</tbody>
</table>
Alkyl Groups

Alkanes can be described by the general formula \( C_nH_{2n+2} \). An alkyl group is formed by removing one hydrogen from the alkane chain and is described by the formula \( C_nH_{2n+1} \). The removal of this hydrogen results in a stem change from \(-ane\) to \(-yl\). Take a look at the following examples.

\[
\begin{align*}
\text{CH}_4 & \rightarrow \text{CH}_3^- \\
\text{Methane} & \rightarrow \text{Methyl} \\
\text{CH}_3\text{CH}_2\text{CH}_3 & \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2^- \\
\text{Propane} & \rightarrow \text{Propyl}
\end{align*}
\]

The same concept can be applied to any of the straight chain alkane names provided in Table \(\PageIndex{2}\).

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Name & Molecular Formula & Condensed Structural Formula \\
\hline
Methane & \text{CH}_4 & \text{CH}_4 \\
\hline
Ethane & \text{C}_2\text{H}_6 & \text{CH}_3\text{CH}_3 \\
\hline
Propane & \text{C}_3\text{H}_8 & \text{CH}_3\text{CH}_2\text{CH}_3 \\
\hline
Butane & \text{C}_4\text{H}_{10} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Pentane & \text{C}_5\text{H}_{12} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Hexane & \text{C}_6\text{H}_{14} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Heptane & \text{C}_7\text{H}_{16} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Octane & \text{C}_8\text{H}_{18} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Nonane & \text{C}_9\text{H}_{20} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Decane & \text{C}_{10}\text{H}_{22} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Undecane & \text{C}_{11}\text{H}_{24} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Dodecane & \text{C}_{12}\text{H}_{26} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Tridecane & \text{C}_{13}\text{H}_{28} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Tetradecane & \text{C}_{14}\text{H}_{30} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
Pentadecane & \text{C}_{15}\text{H}_{32} & \text{CH}_3(\text{CH}_2)\text{CH}_3 \\
\hline
\end{tabular}
\end{table}
<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Condensed Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexadecane</td>
<td>C₁₆H₃₄</td>
<td>CH₃(CH₂)₁₄CH₃</td>
</tr>
<tr>
<td>Heptadecane</td>
<td>C₁₇H₃₆</td>
<td>CH₃(CH₂)₁₅CH₃</td>
</tr>
<tr>
<td>Octadecane</td>
<td>C₁₈H₃₈</td>
<td>CH₃(CH₂)₁₆CH₃</td>
</tr>
<tr>
<td>Nonadecane</td>
<td>C₁₉H₄₀</td>
<td>CH₃(CH₂)₁₇CH₃</td>
</tr>
<tr>
<td>Eicosane</td>
<td>C₂₀H₴₂</td>
<td>CH₃(CH₂)₁₈CH₃</td>
</tr>
</tbody>
</table>

**Classification of carbon atoms**

Carbons have a special terminology to describe how many other carbons they are attached to.

- Primary carbons (1°) attached to one other C atom
- Secondary carbons (2°) are attached to two other C’s
- Tertiary carbons (3°) are attached to three other C’s
- Quaternary carbons (4°) are attached to four C’s

Example \(\PageIndex{1}\)

You will find that hydrogen atoms are also classified in this manner. A hydrogen atom attached to a primary carbon atom is called a primary hydrogen; thus, isobutane, has nine primary hydrogens and one tertiary hydrogen.
• Primary hydrogens (1°) are attached to carbons bonded to one other C atom
• Secondary hydrogens (2°) are attached to carbons bonded to two other C’s
• Tertiary hydrogens (3°) are attached to carbons bonded to three other C’s

Example \( \PageIndex{2} \)

Exercises

Questions

Q3.3.1

Consider the following molecule. How many carbons are in the longest chain? Find a primary and quaternary carbon, and label an ethyl group.
A = $4^\text{o}$ Carbon

B = Ethyl Group

C = $1^\text{o}$ Carbon

The longest chain is 10 carbons long

Contributors

- Dr. Dietmar Kennepohl, FCIC (Professor of Chemistry, Athabasca University)
- Prof. Steven Farmer, Sonoma State University