Reading: Chapter 4
Practice Problems: in text problems

Alkenes: Structure, Nomenclature, Stability, and an Introduction to Reactivity

**ALKENES**

Alkenes are unsaturated hydrocarbons containing a carbon–carbon double bond—that is, two adjacent carbon atoms joined together with two bonds.

The general formula for an alkene is $C_nH_{2n}$, where $n$ is an integer greater than 1.

The first (smallest) member of the alkene family is $C_2H_4$ (IUPAC name, ethene; common name, ethylene).
ALKENES

The alkenes are nonpolar compounds with physical properties similar to those of the alkanes.

They are insoluble in water and have boiling points close to those of the alkanes.

There is more variation in melting points among the alkenes than among the alkanes.

<table>
<thead>
<tr>
<th>#</th>
<th>Molecular formula</th>
<th>Condensed structural formula</th>
<th>Name</th>
<th>Melting point (°C)</th>
<th>Boiling point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>C₂H₄</td>
<td>CH₂=CH₂</td>
<td>Ethene</td>
<td>-160</td>
<td>104</td>
</tr>
<tr>
<td>3</td>
<td>C₃H₆</td>
<td>CH₃=CH₂</td>
<td>Propene</td>
<td>-45</td>
<td>-47</td>
</tr>
<tr>
<td>4</td>
<td>C₄H₈</td>
<td>CH₃=CH=CH₃</td>
<td>1-butene</td>
<td>-185</td>
<td>-6</td>
</tr>
<tr>
<td>5</td>
<td>C₅H₁₀</td>
<td>CH₂=CH=CH₂(CH₃)</td>
<td>1-pentene</td>
<td>-138</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>C₆H₁₂</td>
<td>CH₂=CH=CH₂(CH₂)CH₃</td>
<td>1-hexene</td>
<td>-140</td>
<td>63</td>
</tr>
<tr>
<td>7</td>
<td>C₇H₁₄</td>
<td>CH₂=CH=CH₂(CH₃)CH₂CH₃</td>
<td>1-heptene</td>
<td>-119</td>
<td>94</td>
</tr>
<tr>
<td>8</td>
<td>C₈H₁₈</td>
<td>CH₂=CH=CH₂(CH₂)CH₂CH₃</td>
<td>1-octene</td>
<td>-192</td>
<td>121</td>
</tr>
<tr>
<td>9</td>
<td>C₉H₂₀</td>
<td>CH₂=CH=CH₂(CH₂)CH₂CH₂CH₃</td>
<td>1-decene</td>
<td>-81</td>
<td>146</td>
</tr>
<tr>
<td>10</td>
<td>C₁₀H₂₂</td>
<td>CH₂=CH=CH₂(CH₂)CH₂CH₂CH₂CH₃</td>
<td>1-dodecene</td>
<td>-66</td>
<td>171</td>
</tr>
</tbody>
</table>

BONDING IN ALKENES

Although the two bonds in the structural formula of an alkene are drawn having equal weight, their bond strengths are quite different.

One strong bond: 355 kJ/mol sigma (σ) bond
One weaker bond: 250 kJ/mol pi (π) bond

The weaker π bond is responsible for the increased reactivity of alkenes over the alkanes.

The σ bond in either class of molecules has about the same energy.
The three sp\(^2\) orbitals point to the corners of an equilateral triangle and the remaining p orbital lies perpendicular to the plane of the triangle:

\[ \text{sp}^2 \text{ carbon} \]

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C\(_2\)H\(_4\), ethene, is formed from two sp\(^2\) hybridized carbon atoms and four hydrogen atoms:

Lateral overlap of the unhybridized p orbitals, above and below the triangular planes, results in the \(\pi\) bond of the double bond.
The two carbons and all four hydrogens all lie within the same plane. The bond angles are all 120°.

**Introduction**

- Typical representatives are
  - Ethene, plant growth hormone
Introduction

• Typical representatives are
  – citronellol,
  
  \[ \text{Geranium “Mavis Simpson”} \]

• Typical representatives are
  – limonene,
NAMING ALKENES

Rules for naming alkenes

* For IUPAC nomenclature purposes, the longest continuous chain is redefined as the longest continuous chain containing both carbons of the double bond. For some alkenes, this chain may not be the longest continuous chain of carbons in the molecule.
* The family ending of the name is changed from -ane to -ene.
* The longest continuous chain is numbered from the end nearest the double bond. The position of the double bond is indicated by placing the lower of the two numbers for the double-bond carbons in front of the base name of the compound. (For ethene and propene, the number 1 is not required to indicate the position of the double bond, because there is only one possible placement of the double bond.)
* The names of substituents are used as prefixes, preceded by numbers that indicate their positions on the longest chain.

NAMING ALKENES

* A compound with two double bonds, called a diene, is given the ending -diene instead of -ene. Two numbers are then provided, specifying the position of each double bond.
* A cyclic compound with a double bond in the ring is named as a cycloalkene. Numbering of the ring starts at one of the carbons of the double bond and proceeds through the other carbon of the double bond to substituents on the ring in the direction that yields the lower numbers for the substituents.
Nomenclature of Alkenes

2-butene

Electrostatic map shows high electron density at double bond

Nomenclature of Alkenes

2-hexene

p bond
### Example 12.3 Using the IUPAC nomenclature system to name alkenes

What is the IUPAC name for each of the following compounds?

(a) $\text{CH}_3\text{CH}=\text{CH}-\text{CH}_2\text{CH}_3$

(b) ![Cyclohexene](image)

(c) $\text{CH}_2\text{=CH-CH}=\text{CH-CH}_3$

<table>
<thead>
<tr>
<th>Compound</th>
<th>IUPAC Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{CH}_3\text{CH}=\text{CH}-\text{CH}_2\text{CH}_3$</td>
<td>1-Methyl-1-buten</td>
</tr>
<tr>
<td>$\text{CH}_2\text{=CH-CH}=\text{CH-CH}_3$</td>
<td>3-Methyl-1,3-diene</td>
</tr>
</tbody>
</table>

*The $p-p\pi$ bond restricts free rotation.*

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### cis/trans Isomers

- **$sp^2-sp^2\sigma$**
- **$p-p\pi$ bond side view**
- **$p-p\pi$ bond front view**

The $p-p\pi$ bond restricts free rotation.
**cis/trans Isomers**

Upon rotation we lose $p-p$ overlap, thus rotation doesn’t happen (easily).

Consequently, *geometrical isomers* exist.

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**cis/trans Isomers**

- **cis**
  - All substituents are on one side of $\pi$ bond

- **trans**
  - All substituents are on different sides of $\pi$ bond
**cis/trans Isomers**

**cis-2-pentene**

**trans-3-heptene**
**cis/trans Isomers**

The main chain determines *cis/trans* in the name.

- **cis-3-methyl-2-hexene**
- **trans-3-methyl-2-hexene**

This compound is *cis* but the two methyl groups are ... *trans* to each other.

This compound is *trans* but the two methyl groups are ... *cis* to each other.

*cis* and *trans* are also used to designate the relative position of two groups.

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**E/Z System**

For more than two substituents the *cis/trans* system cannot be used.

A new system, the *E/Z* system is introduced.

To use the *E/Z* system we need to assign priorities to each substituent on each carbon.
**E/Z System**

In case high priorities are on the same side, we assign a **Z configuration**.

In case high priorities are on opposite sides, we assign an **E configuration**.

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**E/Z System**

Priorities are first assigned based on atomic numbers.

(E)-3-fluoro-2-iodo-2-propene

(Z)-3-fluoro-2-iodo-2-propene
**E/Z System**

If you can’t decide using the first atoms attached, go out to the next atoms attached. If there are nonequivalent paths, always follow the path with atoms of higher atomic number.

**Atoms in double bonds are “replicated” at either end of the double bond.**
E/Z System

Name the following compound:

\[
\begin{align*}
\text{CH}_3 \\
\text{H} \\
\text{H} \\
\text{H}_3\text{C} \\
\text{H} \\
\end{align*}
\]

\[
\text{CH}_2
\]

? 

Stability

The stability of alkenes depends upon number of substituents

The more substituents, the more stable
Stability
Steric repulsion is responsible for energy differences among the disubstituted alkenes