Chemistry 11

Book 2

Name:_____________________ Block:________
THE PROPERTIES OF ALKANES

- Alkanes are very unreactive because C–C and C–H bonds are strong and not easily broken.
- Methane, ethane, propane and butane are gases at room temperature (butane is easily liquified under pressure). Pentane and longer chains are liquids.
- Very long chains (C_{16}H_{34} and longer) are solids and are commonly called WAXES or PARAFFINS.

Cycloalkanes

Carbon atoms may bond to each other and form a _________________________structure called a ring, like the one in the diagram below. The hormones ________________________and  ________________________are examples of compounds that contain ring structures.

Consider the molecule shown in Figure 8.1.4(a).
This compound has the formula C_5H_{10}.
Alkanes have the general formula C_nH_{(2n+2)}.
What is the general formula for a cycloalkane like the one in the diagram below? ________________________

![Figure 8.1.4](a) C_5H_{10}; (b) the carbon skeleton formula for C_5H_{10}

To make cyclic compounds easier to draw, a shorthand notation is used in which the hydrogens and carbons which are part of the ring are not represented at all. The rings are represented by lines, and a carbon atom is assumed to be present at each angle in the ring. The proper number of hydrogen atoms is assumed to be attached to each carbon.

For example:

\[
\text{cyclopropane} = C_3H_6 = \quad \text{cyclopentane} = C_5H_{10} = \\
\]

\[
\text{cyclobutane} = C_4H_8 = \quad \text{cyclohexane} = C_6H_{12} = \\
\]

Name this compound → 

Figure 8.1.4 (a) C_5H_{10} (b) the carbon skeleton formula for C_5H_{10}
Rules for Naming:
When naming an alkane that contains a ring structure, the same rules apply as for a chain alkane.

1. The ring that contains the ______________ number of carbon atoms is the ______________ chain.
   The prefix "cyclo" is placed before the parent chain name.

2. The carbon atoms in the parent ring are numbered either ______________ or counterclockwise so that the
   ______________ numbers are used to identify the placement of the ____________________

3. If the ring structure is not the ______________ chain...
   ...then the ring is named as a ______________ with the prefix "________" and ends in "______".

(a) 1-ethyl-2,5-dimethylcycloheptane
(b) 2-cyclobutylpentane

Figure 8.1.5 Example of alkanes that contain ring structures

Problem 8. Name the cyclic molecules below.

a. ____________________  b. ____________________  c. ____________________

SUBSTITUTED CYCLOALKANES

RULE: Substituted cycloalkanes follow the same rules as straight-chain alkanes, except that
   • a single substituent does not use a number to indicate the position of attachment (all carbons
     in the cycloalkyl group are identical).
   • if there is more than one substituent, the first substituent is assumed to be at the “1” position
     and the remaining substituents are numbered either clockwise or anticlockwise so as to have
     the lowest set of overall values.

EXAMPLE: H₂C — CH₂ = methylcyclohexane
Examples of Branched Cycloalkanes:

A) \[
\begin{array}{c}
\text{H}_2\text{C} \\
\text{H}_2\text{C} \\
\text{C} \\
\text{H}_2\text{CH}_3 \\
\text{CH}_3
\end{array}
\]
This is called 1-ethyl-2-methylcyclopentane

B) \[
\begin{array}{c}
\text{H}_2\text{C} \\
\text{H}_2\text{C} \\
\text{C} \\
\text{H}_2\text{CH}_3 \\
\text{CH}_3
\end{array}
\]
This is called 1,2-dimethylcyclopentane

(It is NOT called 1,5-dimethylcyclopentane)

Problem 9. Name the cyclic alkanes shown below:

a. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_2\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

b. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

c. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

d. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_2\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

e. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

f. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

g. \[
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_2\text{CH}_2\text{CH}_3
\end{array}
\]
Problem 10: Sketch the following compounds

(a) 1,2-dimethylcyclobutane  
(b) 1,1,2-trimethylcyclopropane  
(c) 1,3-dipropylcyclopentane  
(d) propylcyclopropane  
(e) 1,3-diethyl-2,2-dimethylcyclooctane  
(f) 1,2,4-triethylcycloheptane

Alkenes

____________________ are hydrocarbons containing ______________ bonds.

They are ______________. This means that the double bond is a reactive site where other atoms could attach to the carbon skeleton.

They have the general formula ______________.

As you saw above, ______________ have the same general formula as ______________.

Molecules with this general formula contain either one alkane ______________ or one double bond.

The rules for naming alkenes are the same as for alkanes except that an alkene’s parent chain name ends in “ene.” See Figure 8.1.6 for an example.

• The parent chain must _____________________.
• The ______________ of the double bond is indicated in the name by stating the number of the carbon atom in the parent chain that the double bond _________________.
• The parent chain carbon atoms are numbered starting at the end _______________ to the double bond.

Name this example:

A number is not used to locate the double bond in chains which are shorter than four carbons. Two examples are below.

CH₂=CH₂  → This is called ethene, not 1-ethene

CH₃–CH=CH₂  → This is called propene, not 1-propene

Why is it that these two molecules do not require the use of the number? _______________
In some cases, the groups attached to the double-bonded carbon atoms provide for a new type of isomerism, as shown in Figure 8.1.7. ___________ isomers are alkenes that have the same structure, but the orientation of the groups across the double bond are different.

Geometric isomers are also called ___________ isomers.

For example, cis-2-butene has two hydrogen atoms bonded to the double-bonded carbon atoms on the ___________ side of the double bond. Both hydrogen atoms are ___________ the double bond.

trans-2-butene has the groups bonded to the double-bonded carbon atoms on ___________ sides of the double bond. One hydrogen is ___________ the double bond, and the other hydrogen is ___________ the double bond.

Geometric Isomers

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For example, cis-2-butene has two hydrogen atoms bonded to the double-bonded carbon atoms on the ___________ side of the double bond. Both hydrogen atoms are ___________ the double bond.

trans-2-butene has the groups bonded to the double-bonded carbon atoms on ___________ sides of the double bond. One hydrogen is ___________ the double bond, and the other hydrogen is ___________ the double bond.

Figure 8.1.7 Examples of cis-trans isomers
Cis-Trans Isomerization Worksheet

Complete the following questions on a separate piece of paper.

1) Draw the actual shape of the following molecules using condensed structures:
   a. trans-2-hexene  
   b. 3-hexyne 
   c. cis-3-octene  
   d. trans-4-decene 
   e. 2-butyne 
   f. 4-methyl-cis-2-pentene
2) Which of the following molecules can exhibit cis-trans isomerism?
   a. 1-butene  
   b. 3-hexene  
   c. 4-heptyne  
   d. 2-octene  
   e. 3-ethyl-3-hexene  
   f. 2,5-dimthyoctane

3) Name the following as “cis” or “trans” isomers.
   a. \[
   \begin{array}{c}
   \text{CH}_3 - \text{CH}_2 \\
   \text{C} \equiv \text{C} \\
   \text{C} \equiv \text{C} \\
   \text{CH}_2 - \text{CH}_3
   \end{array}
   \]
   b. \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \equiv \text{C} \\
   \text{C} \equiv \text{C} \\
   \text{CH}_2 - \text{CH}_3
   \end{array}
   \]
   c. \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \equiv \text{C} \\
   \text{C} \equiv \text{C} \\
   \text{CH}_3
   \end{array}
   \]
   d. \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \equiv \text{C} \\
   \text{C} \equiv \text{C} \\
   \text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3
   \end{array}
   \]
SECTION 25.9 Naming Cycloalkenes

Cycloalkenes are named similarly to straight chained alkenes. The carbons in the ring that contain the double bond are always assigned the #1 and #2 positions, so numbers are used only to locate the positions of substituents attached to the ring - not to locate the position of the double bond. The general formula for cyclic alkenes is C₇H₁₂₋₂. Study the examples below.

![cyclobutene](image1)
3-methylcyclohexene
3,4-dimethylcyclopentene

**Problem 11.** Name the following cycloalkenes.

a. ![cycloalkene](image2)

b. ![cycloalkene](image3)

c. ![cycloalkene](image4)

d. ![cycloalkene](image5)

e. ![cycloalkene](image6)

f. ![cycloalkene](image7)
Alkynes are hydrocarbons containing triple bonds. They are also unsaturated. They have the general formula \( \text{C}_n\text{H}_{2n-2} \).

The rules for naming alkynes are the same as for alkanes except the parent chain name ends in “-yne.” See Figure 8.1.8 for an example.

- The parent chain \( \text{CH}_3\text{CH}_2\text{CHC} = \text{CH} \) \( \text{CH}_3 \) Figure
  - The parent chain \( \text{CH}_3\text{CH}_2\text{CHC} = \text{CH} \) \( \text{CH}_3 \) Figure 8.1.8 3-methyl-1-pentyne

Additional Rules for the Nomenclature of Alkynes:

RULE 1: The chain chosen as the parent chain must contain the carbon-carbon triple bond.

RULE 2: The parent chain must be numbered to give the carbon-carbon triple bond the lowest possible number.

RULE 3: The name of the alkyne must contain a number to indicate the position of the triple bond.

As was the case with the alkenes, no number is used to locate the triple bond if the parent chain is shorter than four carbons:

\[
\begin{align*}
\text{CH} & = \text{CH} \\
\text{CH} & = \text{C} - \text{CH}_3 \\
\text{CH} & = \text{C} - \text{CH}_2 - \text{CH}_3 \\
\text{CH}_3 & = \text{C} = \text{C} - \text{CH}_3
\end{align*}
\]

For the example at right, the correct name is \( \text{CH}_3 - \text{C} = \text{C} - \text{CH}_2 - \text{C} - \text{CH}_3 \) \( \text{CH}_3 \) Figure 8.1.8 3-methyl-1-pentyne

**Problem 12.** Name the alkynes drawn below. Be sure to number the parent chain so as to give the triple bond the lowest possible number.

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

b. \( \text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{C} = \text{C} - \text{CH}_3 \)

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

d. \( \text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{C} = \text{CH} \)

e. \( \text{CH}_3 - \text{C} = \text{C} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \)
EXERCISES:

Look at the examples above (except for the cyclopentene) and decide on the general formula relating the ratio of carbons to hydrogens for each of the following.

(a) an alkene  (b) an alkyne
Express your answer in a form similar to the expression \(C_nH_{2n+2}\) which was found for alkanes.

22. Draw the condensed structure for the following.
   (a) 1-hexene   (c) 3-decene   (e) 2-octene
   (b) 4-nonyn   (d) 2-heptyne   (f) 1-octyne

23. Name the following.
   (a) \(CH_3-CH_2-CH=CH-CH_2-CH_3\)
   (b) \(CH_3-CH_2-CH_2-CH_2-CH_2-C≡CH\)
   (c) \(CH_3-CH_2-CH_2-C≡C-CH_2-CH_2-CH_2-CH_2-CH_3\)
   (d) \(CH_3-CH_2-CH=CH-CH_2-CH_2-CH_3\)

24. Draw the condensed structure for each of the following.
   (a) 4-ethyl-3-methyl-2-hexene   (e) dimethyl-2-butene
   (b) 3-methyl-4-octyne   (f) 3,6-dimethyl-1-cyclohexene
   (c) 1-ethyl-1-cyclohexene   (g) cyclopropyne
   (d) 3-ethyl-4-methyl-1-hexyne   (h) 1,3-dimethyl-1-cyclopentene
Aromatic Hydrocarbons

Benzene is a hydrocarbon with______________________ atoms in a ring. This structure is called a_____________________. It has the molecular formula____________________. The bonds between each carbon atom are slightly longer than a double bond, but slightly shorter than a single bond. The electrons in the benzene molecule are____________________ meaning that they are spread across more than one atom. In other words, there is more than one way to draw its Lewis structure. Equivalent Lewis structures are called____________________ structures.

We can represent benzene using the resonance structure shown in Figure 8.1.9(a) and Figure 8.1.9(b) below.

![Figure 8.1.9 Examples of resonance structures for benzene](image)

Benzene’s resonance structures give it unusual stability; that is, it is highly resistant to chemical attack. Atoms attached to the benzene ring can be replaced, but only the strongest chemical attack (such as combustion) will affect the ring itself.

The benzene ring, also known as an “aromatic ring,” is present in a large number of molecules and many molecules contain two or more aromatic rings joined together.

**Definition:** An AROMATIC MOLECULE is a molecule containing one or more benzene rings.

The aromatic ring (benzene ring) is frequently shown as: \[ \text{ benzene ring } \].

____________________hydrocarbons always contain at least one____________________ ring.

When one of the____________________ atoms in a benzene ring is replaced by another atom or group, we call it a monosubstituted benzene.

Monosubstituted benzenes are named by simply using the name of the substituted group as a____________________ attached to “benzene.”

If____________________ than one hydrogen atom in a benzene has been replaced, we call it a polysubstituted benzene. For polysubstituted benzenes, b____________________and their “address” on the benzene ring is indicated in a similar way to that used for cycloalkanes. We label the first substituted carbon as_____and proceed either clockwise or counterclockwise in such a way as to give the____________________ combination of numbers of substituted carbons.

**For benzenes where only two branches exist on the ring, the three possible 1,2-, 1,3-, and 1,4- positions can also be indicated using the prefixes “ortho,” “meta,” and “para” respectively. These prefixes describe how close the branches are to each other on the benzene ring (Figure 8.1.10). A benzene ring with one methyl branch is commonly called toluene. A benzene ring with two methyl branches is commonly called xylene.**
The naming of simple aromatic compounds formed by adding groups to a benzene ring is almost identical to the naming procedure used for other cyclic hydrocarbons. Two exercises on the next page allow you to apply what you know to naming aromatic compounds.

The example molecules which follow do not have to be memorized; they are shown for your information.

**Figure 8.1.12 Examples of common aromatic compounds**

**EXERCISES:**

29. (a) One resonance structure was drawn for naphthalene (above). Draw two other resonance structures.
   (b) One resonance structure was drawn for anthracene (above). Draw three other resonance structures.

30. Draw the structures of the following compounds.
   (a) 1,3,5-trimethylbenzene
   (b) 1-bromo-4-chlorobenzene
   (c) fluorobenzene
   (d) 1,4-dibromo-2-methylbenzene
   (e) 1,3-diethylbenzene
   (f) hexylbenzene

31. Name the following compounds.
   (a) [Diagram of a benzene ring with a methyl group on the 1 position]
   (b) [Diagram of a benzene ring with a methyl group on the 2 position and a bromine on the 3 position]
   (c) [Diagram of a benzene ring with three chlorine atoms on the 1, 3, and 5 positions]
   (d) [Diagram of a benzene ring with two methyl groups on the 1 and 3 positions]
   (e) [Diagram of a benzene ring with a methyl and an ethyl group on the 1 and 4 positions]
   (f) [Diagram of a benzene ring with a methyl and an ethyl group on the 1 and 3 positions]
**SECTION 25.11  Review Problems**

**Problem 13.** The names of the compounds listed below are NOT correct. Using the incorrect name, draw the structural formula in the work area. Then write the correct name of each compound on the line provided.

<table>
<thead>
<tr>
<th>Incorrect Name</th>
<th>Correct Name</th>
<th>Work Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 4,4-dimethylhexane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. 2-n-propylpentane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. 1,1-diethylbutane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. 1,4-dimethylcyclobutane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. 3-methyl-2-butene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. 5-ethylcyclopentene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. 2-n-propyl-1-propene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. 2-isopropyl-3-heptene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. 2,2-dimethyl-3-butyne</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j. 5-octyne</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Problem 14.** Write condensed structural formulas for the following:

<table>
<thead>
<tr>
<th>Name</th>
<th>Condensed Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 4-isopropyloctane</td>
<td></td>
</tr>
<tr>
<td>b. 3,4-dimethyl-4-n-propylheptane</td>
<td></td>
</tr>
<tr>
<td>c. 1,1-dimethylcyclobutane</td>
<td></td>
</tr>
<tr>
<td>d. 3-ethyl-3-heptene</td>
<td></td>
</tr>
<tr>
<td>e. 3-ethyl-2-methyl-1-hexene</td>
<td></td>
</tr>
<tr>
<td>f. 3-octene</td>
<td></td>
</tr>
<tr>
<td>g. 3,3-dimethyl-1-butyne</td>
<td></td>
</tr>
<tr>
<td>h. 4,4-dimethyl-2-pentyne</td>
<td></td>
</tr>
<tr>
<td>i. 3-n-butyl-2-ethylcyclohexene</td>
<td></td>
</tr>
<tr>
<td>j. 3,4-diethyl-4,6-dimethylnonane</td>
<td></td>
</tr>
</tbody>
</table>