Chapter 12 – Introduction to Organic Chemistry: Hydrocarbons

<table>
<thead>
<tr>
<th>Family</th>
<th>Structure</th>
<th>IUPAC Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkane</td>
<td>CH₃—CH₂—CH₃</td>
<td>Propane</td>
<td></td>
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<tr>
<td></td>
<td>CH₃—CH—CH₂—CH₃</td>
<td>2-Methylbutane</td>
<td>Isopentane</td>
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<tr>
<td>Haloalkane</td>
<td>CH₃—CH₂—CH₂—Cl</td>
<td>1-Chloropropane</td>
<td>Propyl chloride</td>
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<tr>
<td>Cycloalkane</td>
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<td></td>
<td></td>
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<tr>
<td>Alkene</td>
<td>CH₃—CH═CH₂</td>
<td>Propene</td>
<td>Propylene</td>
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<tr>
<td></td>
<td></td>
<td>cis-1,2-Dibromoethene</td>
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<tr>
<td></td>
<td>Br—C═C—Br</td>
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<tr>
<td></td>
<td>H</td>
<td>trans-1,2-Dibromoethene</td>
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</tr>
<tr>
<td></td>
<td>H—C═C—H</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Br</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycloalkene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkyne</td>
<td>CH₃—C≡CH</td>
<td>Propyne</td>
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</tr>
<tr>
<td>Aromatic</td>
<td></td>
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<tr>
<td></td>
<td>CH₃—</td>
<td>Methylbenzene; toluene</td>
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</tr>
<tr>
<td></td>
<td>Cl</td>
<td>1,3-Dichlorobenzene</td>
<td>m-Dichlorobenzene</td>
</tr>
<tr>
<td></td>
<td>Cl</td>
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</tr>
</tbody>
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Section 12.1 – Alkanes

Goal: Identify properties characteristic of organic or inorganic compounds.

Summary:

**Organic compounds**: always contain carbon and hydrogen (thought sometimes other nonmetals as well.)

**Inorganic compounds**: all other compounds. Often ionic (metal + nonmetal)

<table>
<thead>
<tr>
<th>Organic compounds</th>
<th>Inorganic compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covalent bonds</td>
<td>Often ionic or contain polar covalent bonds</td>
</tr>
<tr>
<td>Most form nonpolar molecules</td>
<td>Usually soluble in water</td>
</tr>
<tr>
<td>Low melting and boiling points</td>
<td>High melting and boiling points</td>
</tr>
<tr>
<td>Not very soluble in water</td>
<td>Most are soluble, unless nonpolar</td>
</tr>
<tr>
<td>Dissolve as molecules in solutions (not ions)</td>
<td>Produce ions in water</td>
</tr>
<tr>
<td>Burn vigorously in air</td>
<td>Do not burn in air</td>
</tr>
</tbody>
</table>

Each carbon atom covalently bonds 4 times (due to its 4 valence electrons). When 4 individual groups are attached to a carbon, it has a tetrahedral geometry.
Practice Problems

1. Identify each of the following as a formula of an organic or inorganic compound:
   a. KCl
   b. C₄H₁₀
   c. C₂H₆O
   d. H₂SO₄
   e. CaCl₂
   f. C₃H₇Cl

2. Identify each of the following as a formula of an organic or inorganic compound:
   a. C₆H₁₂O₆
   b. K₃PO₄
   c. I₂
   d. C₂H₆S
   e. C₁₀H₂₂
   f. C₄H₉Br

3. Identify each of the following properties as more typical of an organic or inorganic compound:
   a. is soluble in water
   b. has a low boiling point
   c. contains carbon and hydrogen
   d. contains ionic bonds

4. Identify each of the following properties as more typical of an organic or inorganic compound:
   a. contains Li and F
   b. is a gas at room temperature
   c. contains covalent bonds
   d. produces ions in water

5. In a propane molecule with three carbon atoms, what is the shape around each carbon? (carbon is black, hydrogen is white)
   a. trigonal planar
   b. tetrahedral
   c. square planar
   d. trigonal bipyramidal
   e. linear

![Propane](image)
Section 12.2 – Alkanes

**Goal:** Write the IUPAC names and draw the condensed or line-angle structural formulas for alkanes and cycloalkanes.

**Summary:**

**Alkanes:** a type of hydrocarbon in which the carbon atoms are connected on by *single bonds*.

To name alkanes (no substituents), “*[prefix]ane*”

The prefix refers to the number of carbons in the chain:

- meth (1), eth (2), prop (3), but (4), pent (5), hex (6), hept (7), oct (8), non (9), dec (10)

If the carbon chain is connected in a *ring*, use “*cyclo*” at the beginning of the name (before the prefix)

**Example** name the following:

![Diagram of alkane molecule]

**Solution:** An alkane with a give-carbon chain is name with the prefix *pent* followed by *ane*, which is *pentane*

There are several ways to draw molecules. The following two ways are simplified forms that make life easier and drawing quicker. Note in the line-angle form, the carbons are at each end of a line and the hydrogens are assumed. (There’s always enough H’s to give each C 4 bonds.)

![Diagram of line-angle structural formula]

**Practice Problems**

6. Give the IUPAC name for the following alkane or cycloalkane: (carbon black, hydrogen white)
   a. hexane
   b. pentane
   c. butane
   d. cyclobutane
   e. cyclopentane

7. Give the IUPAC name for the following alkane or cycloalkane:
   a. methane
   b. methene
   c. ethane
   d. octane
   e. propane
8. Give the IUPAC name for the following alkane or cycloalkane:
   a. hexene
   b. butane
   c. pentane
   d. hexane
   e. heptane

9. Give the IUPAC name for the following alkane or cycloalkane:
   a. cycloheptane
   b. octane
   c. cyclohexane
   d. heptane
   e. 2-cyclohexane

10. Give the IUPAC name for the following alkane or cycloalkane:
    a. oneane
    b. butane
    c. propane
    d. ethane
    e. methane

11. Give the IUPAC name for the following alkane or cycloalkane: (black carbon, white hydrogen)
    a. pentane
    b. methane
    c. butane
    d. propane
    e. ethane

12. Give the IUPAC name for the following alkane or cycloalkane:
    a. nonane
    b. propane
    c. octane
    d. heptane
    e. hexane

13. Give the IUPAC name for the following alkane or cycloalkane:
    a. decane
    b. nonane
    c. octane
    d. heptane
    e. hexane

    a. CH₃
    b. CH₄
    c. CH₃-CH₃
    d. CH₃-CH₂-CH₃
    e. CH₃-CH₂-CH₂-CH₃
15. Draw the condensed structure formula for: ethane.
   a. CH₄
   b. CH₃-CH₃
   c. CH₃-CH₂-CH₃
   d. CH₃-CH₂-CH₂-CH₃
   e. CH₃-CH₂-CH₂-CH₂-CH₃

   a. CH₃-CH₂-CH₃
   b. CH₃-CH₂-CH₂-CH₃
   c. CH₃-CH₂-CH₂-CH₂-CH₃
   d. CH₃-CH₂-CH₂-CH₂-CH₂-CH₃
   e. CH₃-CH₂-CH₂-CH₂-CH₂-CH₂-CH₃

17. Draw the line-angle structural formula for: cyclopropane.

18. Draw the condensed structural formula for: propane.
   a. CH₃-CH₃
   b. CH₃-CH₂-CH₃
   c. CH₃-CH₂-CH₂-CH₃
   d. CH₄


Section 12.3 – Alkanes with Substituents

Goal: Write the IUPAC names for alkanes with substituents and draw their condensed and line-angle structural formulas.

Summary:
Structural isomers: are compounds with the same molecular formulas that differ in the order in which their atoms are bonded.

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

Naming alkanes with substituents

2-methylpentane

4-bromo-2,4-dimethylhexane

Guide to Naming Alkanes with Substituents

STEP 1
Write the alkane name for the longest chain of carbon atoms.

STEP 2
Number the carbon atoms starting from the end nearer a substituent.

STEP 3
Give the location and name for each substituent (alphabetical order) as a prefix to the name of the main chain.

Practice Problems

21. Indicate whether the following pair represents structural isomers or the same molecule:

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

and

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

22. Indicate whether the following pair represents structural isomers or the same molecule:

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

and

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

23. Indicate whether the following pair represents structural isomers or the same molecule:

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

and

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

24. Indicate whether the following pair represents structural isomers or the same molecule:

\[
\begin{array}{c}
\text{CH}_3 & \text{CH} & \text{C} & \text{CH}_3 \\
\text{CH}_3 & \text{CH} & \text{CH}_2 & \text{CH}_3
\end{array}
\]

and

\[
\begin{array}{c}
\text{CH}_3 & \text{CH} & \text{C} & \text{CH}_3 \\
\text{CH}_3 & \text{CH} & \text{CH}_2 & \text{CH}_3
\end{array}
\]
<table>
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<tr>
<th>Common Substituents</th>
<th>Substituent</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>methyl</td>
<td>-CH₃</td>
<td><img src="image" alt="methyl" /></td>
</tr>
<tr>
<td>ethyl</td>
<td>-CH₂-CH₃</td>
<td><img src="image" alt="ethyl" /></td>
</tr>
<tr>
<td>propyl</td>
<td>-CH₂-CH₂-CH₃</td>
<td><img src="image" alt="propyl" /></td>
</tr>
<tr>
<td>isopropyl</td>
<td>CH₃-CH₂-CH₃</td>
<td><img src="image" alt="isopropyl" /></td>
</tr>
<tr>
<td>butyl</td>
<td>CH₃-CH₂-CH₂-CH₂-</td>
<td><img src="image" alt="butyl" /></td>
</tr>
<tr>
<td>isobutyl</td>
<td>CH₃-CH-CH₂-</td>
<td><img src="image" alt="isobutyl" /></td>
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<tr>
<td>sec-butyl</td>
<td>CH₃-CH-CH₂-CH₃</td>
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<td>tert-butyl</td>
<td>CH₃-C-CH₃</td>
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<td>phenyl</td>
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<tr>
<td>iodo</td>
<td>-I</td>
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</tbody>
</table>
25. Indicate whether the following pair represents structural isomers or the same molecule:

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 & \quad \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH} & \quad \text{CH} & \quad \text{CH}_2 & \quad \text{CH} & \quad \text{CH}_2 & \quad \text{CH} & \quad \text{CH}_2 & \quad \text{CH} & \quad \text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

and

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{CH} & \quad \text{CH}_2 & \quad \text{CH} & \quad \text{CH}_2 & \quad \text{CH} & \quad \text{CH}_3 & \quad \text{CH}_3 \\
\end{align*}
\]

26. Indicate whether the following pair represents structural isomers or the same molecule:

\[
\begin{align*}
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
\end{align*}
\]

and

\[
\begin{align*}
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
& \quad \text{CH}_3 \\
\end{align*}
\]

27. Give the IUPAC name for the following:
   a. pentane
   b. 2-methylbutane
   c. 2-ethylpropane
   d. 2,2-dimethylpropane
   e. 2,2,2-trimethylethane

28. Give the IUPAC name for the following:
   a. 2,3-dimethylpentan
   b. 1,1,2-trimethylbutane
   c. 3,4-dimethylpentane
   d. dimethylpentane
   e. 2-isopropylbutane

29. Give the IUPAC name for the following:
   a. 2,6-diethyl-4-tert-butylheptane
   b. 4-isopropyl-2,6-dimethylheptane
   c. 4-butane-2,6-methylheptane
   d. 3-isobutyl-2,2,6-trimethylhexane
   e. 4-tert-butyl-2,6-dimethylheptane

30. Give the IUPAC name for the following:
   a. cyclopentane
   b. methylcyclobutane
   c. ethylcyclobutane
   d. 1-ethylcyclobutane
   e. 1-methylcyclobutane

31. Give the IUPAC name for the following:
   a. 1-chloro-3-bromocyclohexane
   b. 1-bromo-3-chlorocyclohexane
   c. 1-chloro-3-bromohexane
   d. 1-bromo-3-chlorocycloheptane
   e. 1-bromo-3-chlorohexane
32. Give the IUPAC name for the following:
   a. 2-methylpentane
   b. 2-methylpentene
   c. methylpentane
   d. 4-methylpentane
   e. 1,1-dimethylbutane

33. Give the IUPAC name for the following:
   a. 3-methyl-4-pentylpentane
   b. 5-pentyl-6-methylpentane
   c. 5-sec-butyldecane
   d. sec-butyldecane
   e. 6-sec-butyldecane

34. Give the IUPAC name for the following:
   a. 3,4-diethylhexane
   b. 3,4-dimethylpentane
   c. 3-ethyl-4-ethylhexane
   d. 3,4-dimethylhexane
   e. 3,4-diethylheptane

35. Give the IUPAC name for the following:
   a. 2-phenylpentane
   b. 2-propylcyclohexane
   c. isopropylcyclohexane
   d. propylcyclohexane
   e. 1-isopropylcyclohexane

36. Give the IUPAC name for the following:
   a. 1,1-dimethylcyclopentane
   b. methylcycloheptane
   c. 2-methylhexane
   d. 1,1-dimethylpentane
   e. methylcyclopentane

37. Draw the condensed structural formula for the following alkane: 3,3-dimethylpentane

38. Draw the condensed structural formula for the following alkane: 2,3,5-trimethylhexane

39. Draw the condensed structural formula for the following alkane: 3-ethyl-5-isopropylcyclohexane

40. Draw the condensed structural formula for the following alkane: 1-bromo-2-chloroethane
41. Draw the condensed structural formula for the following alkane: 3-ethylpentane

42. Draw the condensed structural formula for the following alkane: 4-isopropyl-3-methylheptane

43. Draw the condensed structural formula for the following alkane: 4-ethyl-2,2-dimethyloctane

44. Draw the condensed structural formula for the following alkane: 2-bromopropane.

45. Draw the line-angle structural formula for the following: 3-methylheptane

46. Draw the line-angle structural formula for the following: 1-chloro-3-ethylcyclopentane

47. Draw the line-angle structural formula for the following: bromocyclobutane

48. Draw the line-angle structural formula for the following: 2,3-dichlorohexane

49. Draw the line-angle structural formula for the following: 1-bromo-2-methylpentane

50. Draw the line-angle structural formula for the following: 1,2,3-trimethylchlopropane

51. Draw the line-angle structural formula for the following: ethylcyclohexane
Extra Practice

Give the IUPAC name for each of the following:

1. CH₃-CH₂-C-CH₃
2. CH₃-CH₂-Cl
3. CH₃-CH₂-CH-CH₂-CH₃
4. Br
5. Cl-CH₂-CH-CH₂-Br
6. CH₃-CH-CH-C-CH₃
7. CH₃-CH₂-C-CH₂-CH₃
Section 12.4 – Properties of Alkanes

Goal: Identify the properties of alkanes and write a balanced chemical equation for combustion.

Summary:

As carbon chains get longer, the boiling point increases. This is due to increased surface area for two chains to laying side by side (like spaghetti noodles or licorice) that allows more attractions between the two chains, the stronger the bonds, the higher the temperature has to be to boil.

Branched hydrocarbons have less surface area for two molecules to stack against each other for attractions to occur. For that reason, carbon chains have higher boiling points than branched.

- Cycloalkanes have higher boiling points because the rings can stack, creating more interactions.

- Alkanes readily burn in oxygen to produce carbon dioxide, water, and energy. This is combustion:

\[
\text{Alkane(g)} + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g) + \text{energy}
\]

- Alkanes are nonpolar molecules, are not soluble in water, and usually less dense than water.

Practice Problems

52. Heptane, used as a solvent for rubber cement, has a density of 0.68g/mL and boils at 98°C.
   a. Draw the condensed and line-angle structural formulas for heptane.

   b. Is heptane a solid, liquid, or gas at room temperature?

   c. Is heptane soluble in water?

   d. Will heptane float on water or sink?

   e. Write the balanced chemical equation for the completely combustion of heptane.
53. Nonane has a density of 0.79 g/mL and boils at 151°C.
   a. Draw the condensed and line-angle structural formulas for nonane.
   b. Is nonane a solid, liquid, or gas at room temperature?
   c. Is nonane soluble in water?
   d. Will nonane float on water or sink?
   e. Write the balanced chemical equation for the complete combustion of nonane.

54. Write the balanced chemical equation for the complete combustion of ethane.
   a. C₂H₄ + 3O₂ → 2CO₂ + 2H₂O
   b. 2C₂H₆ + 7O₂ → 4CO₂ + 6H₂O
   c. C₂H₆ + 7/2 O₂ → 2CO₂ + 3H₂O
   d. C₂H₄ + O₂ → CO₂ + H₂O
   e. C₂H₆ + O₂ → CO₂ + H₂O

55. Write the balanced chemical equation for the complete combustion of cyclopropane.
   a. C₃H₈ + O₂ → CO₂ + H₂O
   b. C₃H₈ + 5O₂ → 3CO₂ + 4H₂O
   c. 2C₃H₆ + 2O₂ → CO₂ + 3H₂O
   d. C₃H₆ + O₂ → CO₂ + H₂O
   e. 2C₃H₆ + 9O₂ → 6CO₂ + 6H₂O

56. Write the balanced chemical equation for the complete combustion of octane.
   a. C₈H₁₀ + O₂ → CO₂ + H₂O
   b. 2C₈H₁₈ + 25O₂ → 16CO₂ + 18H₂O
   c. C₈H₁₈ + O₂ → CO₂ + H₂O
   d. C₈H₁₈ + 25/2 O₂ → 8CO₂ + 9H₂O
   e. C₈H₁₀ + O₂ → 4CO₂ + 5H₂O

57. Write the balanced chemical equation for the complete combustion of hexane.
   a. 2C₆H₁₄ + 19O₂ → 12CO₂ + 14H₂O
   b. C₆H₁₄ + 19/2 O₂ → 6CO₂ + 7H₂O
   c. C₂H₆ + 7/2 O₂ → 2CO₂ + 3H₂O
   d. C₂H₄ + O₂ → CO₂ + H₂O
   e. C₂H₆ + O₂ → CO₂ + H₂O

58. Write the balanced chemical equation for the complete combustion of cyclopentane.
   a. 2C₅H₁₀ + 15O₂ → 10H₂O + 10CO₂
   b. C₅H₁₀ + 15/2 O₂ → 5H₂O + 5CO₂
   c. C₅H₁₀ + 15O₂ → 5H₂O + 5CO₂
   d. C₅H₁₂ + 8O₂ → 5H₂O + 6CO₂
   e. C₅H₁₂ + 4O₂ → 5H₂O + 3CO₂
59. Write the balanced chemical equation for the complete combustion of butane.
   a. $C_4H_{10} + 13/2 \text{O}_2 \rightarrow 4\text{H}_2\text{O} + 5\text{CO}_2$
   b. $C_4H_{10} + 13 \text{O}_2 \rightarrow 4\text{H}_2\text{O} + 5\text{CO}_2$
   c. $2C_4H_{10} + 13\text{O}_2 \rightarrow 8\text{H}_2\text{O} + 10\text{CO}_2$
   d. $C_4H_8 + 6\text{O}_2 \rightarrow 4\text{H}_2\text{O} + 4\text{CO}_2$
   e. $C_4H_8 + 3\text{O}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{CO}_2$

60. In each of the following pairs of hydrocarbons, which one would you expect to have the higher boiling point?
   a. pentane or heptane
   b. propane or cyclopropane
   c. hexane or 2-methyl pentane

61. In each of the following pairs of hydrocarbons, which one would you expect to have the higher boiling point?
   a. propane or butane
   b. hexane or cyclohexane
   c. 2,2-dimethylpentane or heptane
Section 12.5 – Alkenes and Alkynes

**Goal:** Identify structural formulas as alkenes, cycloalkenes, and alkynes, and write their IUPAC names.

**Summary:**
Alkenes are hydrocarbons with at least one double bond.
Alkynes are hydrocarbons with at least one triple bond.

The IUPAC names for alkenes end with *ene*, while alkyne names end with *yne.*
The main carbon chain is numbered from the end **nearest to the double or triple bond.**

**Example – Naming alkenes and alkynes**

Write the IUPAC names for the following:

**Solution**

**Step 1:** Name the longest carbon chain that contains the double or triple bond.

- 6 carbons with double bond – hexane
- 6 carbons with triple bond – hexyne

**Step 2:** Number the carbon chain, starting from the end nearer the double or triple bond.

- 2-hexene
- 2-hexyne

**Step 3:** Give the location and name of each substituent (in alphabetical order) as a prefix to the alkene or alkyne name.

- 4-methyl-2-pentene
- 2-hexyne (no substituents)

**Example – naming cycloalkenes**

If no substituents (other than one double bond) do not include numbering (unnecessarily)
If there are substituents, begin numbering with 1 and 2 as the double bond. Then move clockwise or counterclockwise, whichever direction meets the next substituents first.

- Cyclohexene
- 3,3-dimethylcyclopentene
62. Give the IUPAC name for the following:
   a. 2-methyl-1-propane
   b. isopropylethene
   c. methene
   d. butene
   e. 2-methyl-1-propene

63. Give the IUPAC name for the following:
   a. 4-bromo-4-methyl-2-butyne
   b. 2-bromo-3-pentyne
   c. bromopentyn
   d. 4-bromo-2-pentyne
   e. 1-bromo-1methyl-2-butene

64. Give the IUPAC name for the following:
   a. 4-ethyl-cyclopentene
   b. ethylcyclobutene
   c. 4-ethylcyclobutene
   d. 4-ethylcyclopentane
   e. 4-methyl-cyclopentene

65. Give the IUPAC name for the following:
   a. ethylhexene
   b. 3-ethyl-4-hexene
   c. 4-propyl-2-hexene
   d. 4,4-diethyl-2-butene
   e. 4-ethyl-2-hexene

66. Give the IUPAC name for the following:
   a. 5-hexene
   b. 5-heptene
   c. 1-hexene
   d. 1-hexane
   e. 1-heptene

67. Give the IUPAC name for the following:
   a. 6-methyl-2-heptyne
   b. methylhexyne
   c. 2-ethyl-5-hexyne
   d. 6-methyl-2-heptene
   e. 2-methyl-6-heptyne

68. Give the IUPAC name for the following:
   a. 1,4-dimethylcyclohexyne
   b. 2,5-diethylcycloheptene
   c. 1,4-dimethylcyclohexene
   d. 2,4-diethylcycloheptene
   e. 2,5-dimethylcyclohexene
69. Give the IUPAC name for the following:
   a. dichlorohexene
   b. 4,6-dichloro-1-heptene
   c. chloroheptane
   d. 4,6-dichloro-6-methyl-1-hexene
   e. 2,4-dichloro-6-heptene

70. Draw the condensed structural formula of: 1-pentene

71. Draw the condensed structural formula of: 2-methyl-1-butene

72. Draw the line-angle structural formula of: 3-methylcyclohexene

73. Draw the line-angle structural formula of: 1-chloro-3-hexyne

74. Draw the condensed structural formula of: 3-methyl-1-butyne

75. Draw the condensed structural formula of: 3,4-dimethyl-1-pentene

76. Draw the line-angle structural formula of: 1,2-dichlorocyclopentene

77. Draw the line-angle structural formula of: 2-methyl-2-hexene
Section 12.6 – Cis-Trans Isomers

Goal: Draw the condensed and line-angle structural formulas and give the names for the cis-trans isomers of alkenes.

Summary: Geometric or cis-trans isomers of alkenes occur when the carbon atoms in the double bond are connected to different atoms or groups.

Practice Problems

78. Give the IUPAC name for the following, using cis or trans prefixes:
   a. trans-2-butene
   b. trans-2,3-dimethylethene
   c. cis-butene
   d. cis-2-butene
   e. cis-2,3-dimethylethene

79. Give the IUPAC name for the following, using cis or trans prefixes:
   a. trans-3-octene
   b. trans-5-octene
   c. cis-5-octene
   d. cis-1-ethyl-2-butylethene
   e. cis-3-octene

80. Give the IUPAC name for the following, using cis or trans prefixes:
   a. cis-heptene
   b. cis-4-heptene
   c. trans-4-heptene
   d. cis-3-heptene
   e. trans-3-heptene

81. Give the IUPAC name for the following, using cis or trans prefixes:
   a. trans-1-methyl-2-ethylmethene
   b. cis-1-methyl-2-ethylmethene
   c. 2-pentene
   d. cis-2-pentene
   e. trans-2-pentene
82. Give the IUPAC name for the following, using cis or trans prefixes:
   a. cis-2-heptene
   b. trans-2-heptene
   c. cis-1-butyl-2-methylthene
   d. trans-1-butyl-2-methylethene
   e. 2-heptene

83. Give the IUPAC name for the following, using cis or trans prefixes:
   a. cis-4-heptene
   b. trans-4-heptene
   c. trans-3-heptene
   d. cis-3-heptene
   e. 3-heptene

84. Draw the condensed structural formula for: cis-1,2-difluoroethene

85. Draw the condensed structural formula for: trans-1-bromo-2-chloroethene

86. Draw the condensed structural formula for: cis-2-hexene

87. Draw the condensed structural formula for: trans-3-heptene

88. Draw the condensed structural formula for: trans-2-pentene

89. Draw the condensed structural formula for: cis-4-octene

90. Which of the following cannot have cis-trans isomers? (Select all that apply)
   a. H₂C=CH—CH₃
   b. CH₃—CH₂—CH=CH—CH₃
   c. 

91. Which of the following cannot have cis-trans isomers? (Select all that apply)
   a. 
   b. CH₃—CH₂—CH₂—CH=CH₂
   c. 

12.7 – Addition Reactions for Alkenes

Goal: Draw the condensed or line-angle structural formulas and give the names for the organic products of addition reactions of alkenes. Draw a condensed structural formula for a section of a polymer.

Summary:
The addition of small molecules to the double bond is a characteristic reaction of alkenes.

**Hydrogenation** adds hydrogen atoms to the double bond of an alkene to yield an alkane.

\[
\text{H}_2\text{C} = \text{CH}_2 + \text{H}_2 \xrightarrow{\text{Pt}} \text{H}_2\text{C} - \text{CH}_2
\]

**Hydration** adds water to a double bond of an alkene to form an alcohol.
- The H is added to the C with more H’s already attached to it. (Markovnikov’s Rule)

**Polymers** are long-chain molecules that consist of many repeating units of smaller carbon molecules called monomers.
- Many synthetic materials are made using addition reactions in which a catalyst links the carbon atoms from various kinds of alkene molecules (the monomers).
- The name of a polymer is that name of the monomers with “poly” in front. (See equation below.)

**Understanding the Concepts**

What is a polymer?

What is a monomer?

Write an equation that represents the formation of a portion of polypropylene (polypropene) from three of its monomers.
Practice Problems

92. Draw the structural formula for the product in each of the following reactions using Markovnikov’s rule when necessary:

a. \[ \text{CH}_3\text{CH}_2\text{CH}_2\text{CH} \equiv \text{CH}_2 + \text{H}_2 \xrightarrow{\text{Pt}} \]

b. \[ \text{H}_2\text{C} \equiv \text{C} \text{CH}_2\text{CH}_3 + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \]

c. \[ \text{+ H}_2 \xrightarrow{\text{Pt}} \]

d. \[ \text{+ H}_2\text{O} \xrightarrow{\text{H}^+} \]

93. Draw the structural formula for the product in each of the following reactions using Markovnikov’s rule when necessary:

a. \[ \text{CH}_3\text{CH}_2\text{CH} \equiv \text{CH}_2 + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \]

b. \[ \text{+ H}_2 \xrightarrow{\text{Pt}} \]

c. \[ \text{+ H}_2 \xrightarrow{\text{Pt}} \]

d. \[ \text{+ H}_2\text{O} \xrightarrow{\text{H}^+} \]

94. Write an equation that represents the formation of a portion of polystyrene from three of its monomers.

\[ \text{Polystyrene (PS)} \]

95. The plastic polyvinylidene difluoride, PVDF, is made from monomers of 1,1-difluoroethene. Draw the expanded structural formula for a portion of the polymer formed from three monomers of 1,1-difluoroethene.

96. The polymer polyacrylonitrile, PAN, used in the fabric material. Orlon is made from monomers of acrylonitrile. Draw the expanded structural formula for a portion of the polymer formed from three monomers of acrylonitrile.

\[ \text{Acrylonitrile} \]
Section 12.8 – Aromatic Compounds

Goal: Describe the bonding in benzene; name aromatic compounds, and draw their line-angle structural formulas.

Summary:

Aromatic compounds are molecules that contain benzene, \( \text{C}_6\text{H}_6 \), a cyclic structure containing six carbon atoms and six hydrogen atoms.

- The structure of benzene is represented as a hexagon with a circle in the center (far right in image).

The IUPAC system uses the names of benzene, toluene, aniline, and phenol.

- In the IUPAC name, two or more substituents are numbered and listed in alphabetical order. (The same naming scheme as with other rings.)

When a benzene is used as a substituent on a carbon chain, it is called a phenyl group:
Practice Problems

97. Give the IUPAC name for each of the following:

98. Give the IUPAC name for each of the following:

99. Draw the structural formula for each of the following:
   a. 1-bromo-3-chlorobenzene
   b. 1-ethyl-4-methylbenzene
   c. Propylbenzene
   d. 1,2,4-trichlorobenzene