Hydrocarbons

Hydrocarbons are organic compounds composed on only the elements carbon and hydrogen (duh!). Answer some general questions about hydrocarbons.

1. What is a homologous series?

2. What are the general molecular formulas for the homologous series of:
   a. alkanes
   b. alkenes
   c. alkynes

3. How are the physical properties of the members of a homologous series related?

4. How are the various hydrocarbons in petroleum separated?


6. Name the following compounds:

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

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

7. What is the molecular formula for:
   a. 2-pentene
   b. 3-methyl-2-pentene
8. A student incorrectly named a compound 2-propyl-2-pentene. What is the correct name?

9. Draw the carbon backbone structures for all possible structural isomers for C\textsubscript{5}H\textsubscript{12}.

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**Hydrocarbon Boiling Points**

Chemists often gather data regarding physical and chemical properties of substances. Although these data can be organized in many ways, the most useful ways uncover trends or patterns among the values. These patterns often trigger attempts to explain the regularities. The development of the Periodic Table is an example of this approach. In a similar vein, we seek patterns among boiling point data for some hydrocarbons. During evaporation and boiling, individual molecules in the liquid state gain enough energy to overcome intermolecular forces and enter the gaseous state. Boiling point data for several hydrocarbons are given in Table 1.

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Boiling Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butane</td>
<td>-0.5</td>
</tr>
<tr>
<td>Decane</td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>-88.6</td>
</tr>
<tr>
<td>Heptane</td>
<td>98.4</td>
</tr>
<tr>
<td>Hexane</td>
<td>68.7</td>
</tr>
<tr>
<td>Methane</td>
<td>-161.7</td>
</tr>
<tr>
<td>Nonane</td>
<td>150.8</td>
</tr>
<tr>
<td>Octane</td>
<td>125.7</td>
</tr>
<tr>
<td>Pentane</td>
<td>36.1</td>
</tr>
<tr>
<td>Propane</td>
<td>-42.1</td>
</tr>
</tbody>
</table>

1. In what pattern or order are Table 1 data organized?

2. Is the data in Table 1 presented in a useful way? Why or why not?
3. Assume we want to search for a trend or pattern among these boiling point data. Propose a more useful way to arrange these data, and construct a graph based on your idea using the graph below. Don’t forget to properly label the axes, state units, draw a smooth curve, and give a title.

![Graph](image)

4. State the relationship in the data revealed by your graph.

5. Draw a dotted line on the graph to indicate room temperature. Which substances are gases at room temperature?

6. Which substance(s) boil between room temperature and body temperature (37°C)?

7. Extrapolate your graph to predict the boiling point of decane.

8. What can you infer about intermolecular attractions in decane compared with those in butane?

9. What are the intermolecular attractions in hydrocarbons called?
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**Heats of Combustion**

Hydrocarbons will undergo complete combustion (“burn”) in excess oxygen according to the following general equation:

\[ \text{hydrocarbon} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{heat} \]

Data on the heat of combustion of several hydrocarbons is given in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Heat of Combustion of Hydrocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat of Combustion</strong></td>
</tr>
<tr>
<td>Hydrocarbon</td>
</tr>
<tr>
<td>Methane</td>
</tr>
<tr>
<td>Propane</td>
</tr>
<tr>
<td>Pentane</td>
</tr>
<tr>
<td>Heptane</td>
</tr>
<tr>
<td>Decane</td>
</tr>
</tbody>
</table>

1. Fill in all the blanks in Table 2. Be sure to correct for the number of moles given in the equation. You will need to use Regents Table I.

2. Are the combustion of hydrocarbons endothermic or exothermic reactions?

3. Write balanced equations, including the heat released, for the complete combustion of methane (the main component of natural gas) and butane (used in lighter fluid).
   a. methane:

   b. butane:

4. Estimate the heat of combustion of decane in both kJ/g and kJ/mol.
5. In the box below, draw a potential energy diagram for the combustion of octane. Label everything!

6. The heat of combustion of octane is exothermic, meaning the products have a lower energy level than the reactants. Why doesn’t the gasoline (primarily octane) in your car tank spontaneously combust?

7. How much energy is released by the complete combustion of 2.5 mol of gasoline (octane)?

8. How much energy is released by the complete combustion of one gallon of gasoline (1 gal = 2660 g)?

9. (Honors) Suppose your car operates at only 16% efficiency (typical), so that only 16% of the thermal energy from the combustion of octane is actually converted to “wheel turning” mechanical energy. How much useful energy is stored in a 20 gallon tank of gasoline?

10. (Honors) Assuming you heat your home with natural gas (primarily methane), how many liters of natural gas at STP are required to heat a 120 L hot water tank from 20°C to 55°C?