Lab - Modeling Alkanes

Purpose: To identify the bonding properties, general formula and boiling point trends of alkanes.

Directions: In this activity you will assemble models of several simple hydrocarbons. Then, answer the questions with each assembly.

Part 1: Alkane Introduction

Procedure:

1) Assemble a model of methane (CH_4). Compare your model to the Lewis dot structure of methane. Note that the angles defined by the bonds between atoms are not 90°, as you might think by looking at the structural formula. The pyramid shape that this molecule has is given the name tetrahedron. Draw a picture of the model.

2) Compare your three-dimensional model of methane to the structural diagram shown here:

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    H
    |
H – C – H
    |
    H
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a) How does the two-dimensional drawing limit the actual shape of the molecule?

b) Are there features of the two dimensional drawing that are difficult to translate into a three-dimensional structure? Explain.

c) What misconceptions are present in the two dimensional structure that could cause confusion?

3) Assemble models of a two-carbon and a three-carbon alkane molecule. In an alkane, each carbon atom is bonded to four other atoms.
a) How many hydrogen atoms are present in the two-carbon alkane?

b) How many hydrogen atoms are present in the three-carbon alkane?

c) Draw a picture of each molecule.

4a) Draw Lewis dot structures and structural diagrams for the two and three carbon alkanes.

b) The molecular formula for the first alkane is CH_4. What is the molecular formula for the second and third?

Examine your three-carbon alkane model and the structural formula you drew for it. Note that the middle carbon atom is attached to two hydrogen atoms, but the carbon on each end is attached to three hydrogen atoms. This molecule can be represented as CH_3–CH_2–CH_3 or $CH_3CH_2CH_3$. Formulas such as these provide convenient information about how atoms are arranged in molecules. For many purposes, these representations are more useful than molecular formulas such as C_3H_8.

5) Consider the molecular formulas CH_4, C_2H_6 and C_3H_8. Given the pattern represented by the series, try to predict the formula for the four-carbon alkane.

The general molecular formula for all alkane molecules can be written C_nH_{2n+2}, where n is the number of carbon atoms in the molecule.

6) Use the general alkane formula to predict the molecular formula for the rest of the first ten alkanes. After doing this compare your molecular formulas with those given in the Table 1.

The names of the first ten alkanes are also given in Table 1. As you can see, each name is composed of a prefix followed by -ane (designating an alkane). The prefix indicates the number of carbon atoms in the backbone carbon chain. To a chemist, meth- means one carbon atom, eth- means two and so on.

7) Write structural formulas for butane and pentane.

8a) Name the alkanes with these long formulas:

i) $CH_3CH_2\,CH_2\,CH_2\,CH_2\,CH_2\,CH_3$ ii) $CH_3\,CH_2\,CH_2\,CH_2\,CH_2\,CH_2\,CH_2\,CH_2\,CH_2\,CH_3$

b) Write the molecular formula for the two alkanes in question 8a.

9) Write the formula of an alkane containing 25 carbon atoms.

b) Did you write the molecular formula or the long version of this compound? Why?

10) Name the alkane having a molar mass of

a) 30 g/mol	b) 58 g/mol	c) 114 g/mol

Part 2: Trends in Alkane Boiling Points

Procedure:

1) Ask your teacher for a copy of Table 1, information about the first 10 alkanes. Prepare a graph of boiling points. The x-axis scale should range from 1 to 13 carbon atoms (even though you will initially plot data for 1 to 10 carbon atoms). The y-axis scale should extend from -200 °C to +250 °C.

2) Plot the data points. Draw a best-fit line through your data points.

3) Estimate the average change in boiling point (in °C) when one carbon atom and two hydrogen atoms ($-CH_2-$) are added to a particular alkane chain.

4a) Using your graph, estimate the boiling points of undecane ($C_{11}H_{24}$), dodecane ($C_{12}H_{26}$) and tridecane ($C_{13}H_{28}$). To do this, extrapolate your best fit line to pass through the 11 to 13 points of the graph.

b) Compare your results with the actual values provided by your teacher.

5) You learned that a substance's boiling point depends in part on its intermolecular forces (the glue holding molecules together). For the alkanes you have studied, what is the relationship between these attractions and the number of carbon atoms in each molecule?

Conclusion:

Table 1

Name	Number of Carbons	Short Version	Long Version	Boiling Point (°C)
Butane	4	C_4H_{10}	$CH_3\ CH_2\ CH_2\ CH_3$	–0.5
Decane	10	$C_{10}H_{22}$	$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$	174.0
Ethane	2	C_2H_6	$CH_3\ CH_3$	–88.6
Heptane	7	C_7H_{16}	$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$	98.4
Hexane	6	C_6H_{14}	$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$	68.7
Methane	1	CH_4	CH_4	–161.7
Nonane	9	C_9H_{20}	$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$	150.8
Octane	8	C_8H_{18}	$CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$	125.7
Pentane	5	C_5H_{12}	$CH_3\ CH_2\ CH_2\ CH_2\ CH_3$	36.1
Propane	3	C_3H_8	$CH_3\ CH_2\ CH_3$	–42.1