Molecular Models and Isomerism

Introduction:
When two or more compounds have the same molecular formula but different structural arrangements of their atoms, the various individual compounds are called isomers. The ability to have isomers is called isomerism. In this lab, you will construct and study models of isomers to observe their spatial arrangements and the criteria for compounds which have this property.

Bonding rules:
Carbon must have 4 bonds; hydrogen 1 bond; oxygen 2 bonds; and chlorine 1 bond.

Experimental:
Obtain a Model Kit containing a collection of plastic sticks and balls. The black balls with four holes drilled at angles of approximately 109.5° represent carbons. The white balls represent hydrogen. The green balls represent chlorine. The red balls represent oxygen.

Methane, CH₄, can be represented then as shown below:

Model Kit representations
Activities:
A. Construct four methane molecules using 1 carbon atom, 4 hydrogen atoms, and 4 bonds for each molecule. Draw the three-dimensional structure for the CH₄ molecule.

B. Remove one hydrogen from each of two CH₄ molecules. You now have two methyl groups, CH₃⁻. Bond these two methyl groups together using a bond to give a model of ethane, CH₃–CH₃. Draw the three-dimensional structure of this molecule below.

C. Remove an H atom from the ethane molecule and an H atom from another methane molecule. You now have an ethyl, CH₃CH₂⁻, and a methyl CH₃⁻, group. Bond these groups together with a bond to form a molecule of propane, CH₃CH₂CH₃. Draw the three-dimensional structure of this molecule below.
D. Construct two ethyl groups and bond them together. You now have a model of \( n \)-butane, \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 \). Draw the three-dimensional structure of this molecule below.

E. Rearrange the \( n \)-butane model (from part D) to form isobutane by using the following steps: (1) remove one methyl group from the \( n \)-butane model; (2) remove one H from the central carbon atom of the remaining propyl, \( \text{CH}_3\text{CH}_2\text{CH}_2^- \) group. Bond the methyl group to the central carbon atom and the H to the end carbon atom. The compound you now have is isobutane. This molecule and the \( n \)-butane from part D are both isomers of one another – both have the formula, \( \text{C}_4\text{H}_{10} \). Draw the three-dimensional structure of this molecule below.

F. Construct two molecules of propane, \( \text{CH}_3\text{CH}_2\text{CH}_3 \). On one molecule replace an H atom from and end carbon with a Cl atom. On the other molecule replace an H atom from the central carbon atom by a Cl atom. Both molecules are isomers and have the formula, \( \text{C}_3\text{H}_7\text{Cl} \). The first molecule is \( n \)-propyl chloride (IUPAC: 1-chloropropane); the second molecule is isopropyl chloride (IUPAC: 2-chloropropane). Draw the three-dimensional structures of these molecules below.
G. Construct two different molecules, each having the molecular formula C₂H₆O. Follow the bonding rules and the ball colors given on the first page of this lab exercise. One molecule is named dimethyl ether (IUPAC: methoxy methane) and the other one is named ethyl alcohol (IUPAC: ethanol). Draw the three-dimensional structures and name these molecules below.

H. If an H atom is replaced by a Cl atom in a molecule of n-butane, C₄H₁₀, how many structural isomers of chlorobutane, C₄H₉Cl, can be formed? Draw the three-dimensional structures and name these molecules below.

I. If two H atoms are replaced by two Cl atoms in a molecule of ethane, C₂H₆, how many structural isomers of dichloroethane, C₂H₄Cl₂, can be formed? Draw the three-dimensional structures and name these molecules below.
J. If two H atoms are replaced by two Cl atoms in a molecule of propane, C\textsubscript{3}H\textsubscript{8}, how many structural isomers of dichloropropane, C\textsubscript{3}H\textsubscript{6}Cl\textsubscript{2}, can be formed? Draw the three-dimensional structures and name these molecules below.

K. Construct and draw models of the following molecules.

chlorocyclopentane  
1,1-dichlorocyclobutane
L. Construct and draw models of the following molecules.

* cis-1,2-dichlorocyclopropane  
* trans-1,2-dichlorocyclobutane

M. Construct and draw models of the following alkyl groups.

* isopropyl, C₃H₇⁻  
* tert-butyl, C₄H₉⁻