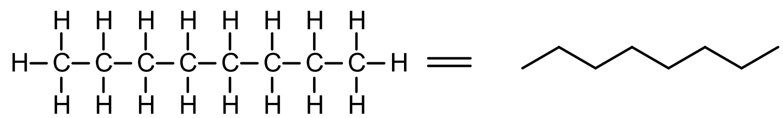
## Experiment 8: Organic Compounds

**Organic chemistry** is the study of substances that are based on carbon atoms (**organic compounds**). In this experiment, you will start with **hydrocarbons** and move on to different types of organic compounds. Hydrocarbons are organic compounds that are composed only of carbon atoms and hydrogen atoms. There are four different types of hydrocarbons: alkanes, alkenes, alkynes, and arenes (aromatic hydrocarbons).

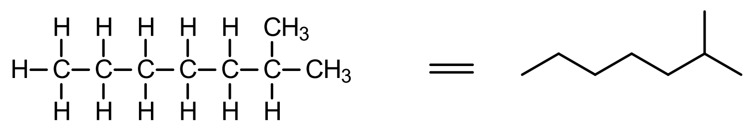
### 1. Alkanes

Alkanes are hydrocarbons that have only single bonds between carbon atoms. Examples are:

octane



2-methylheptane



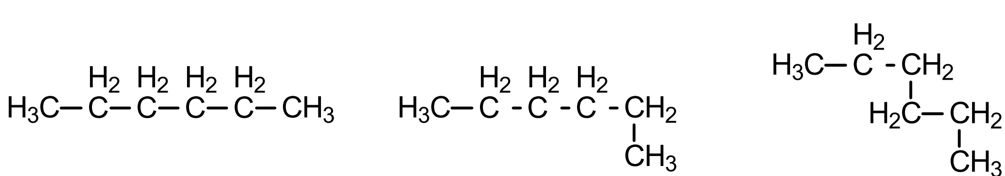
2,2,4-trimethylpentane

2,4-dimethylpentane

Each alkane molecule is drawn by using a **structural formula** and a **line-angle formula**. They are all different molecules and have different names. Although the first three molecules (octane, 2-methyheptane, and 2,2,4-trimethylpentane) share the same molecular formula of $C_8H_{18}$, they are different molecules because carbon and hydrogen atoms are connected in different ways. They are called **constitutional isomers**. The last molecule (2,4-dimethylpentane) is different from the other molecules because it ($C_7H_{16}$) does not share the same molecular formula with the first three molecules ($C_8H_{18}$). 2,4-dimethylpentane is not an isomer with the first three molecules.

Carbon atoms in alkanes have a tetrahedral shape. For example, a structural formula of octane might give you an impression that the molecule is straight. The molecule is not straight due to a tetrahedral shape of each carbon atom. Structural formulas do not express actual shapes of molecules. You will explore this fact by using molecular models in this experiment.

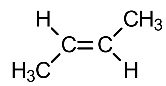
When you consider isomers, it is important to remember that a single bond between carbon atoms could rotate. The rotations of single bonds generate different shapes **(conformations)** of an identical molecule. For example, all the following structures are not isomers. They are all hexane molecules written differently on paper. By using molecular models, you will learn how to identify isomers from different conformations of identical structures.

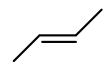


**2. Alkenes**

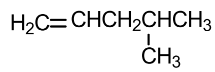
Alkenes are hydrocarbons that have at least one double bond between carbon atoms. Examples are:

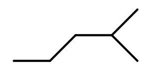
*trans*-2-butene



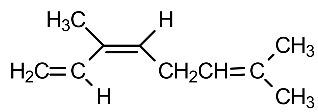


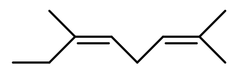
4-methyl-1-pentene





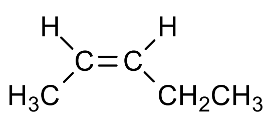
3,7-dimethyl-1,3,6-octatriene

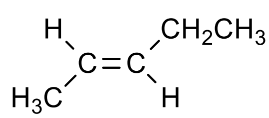




Carbon atoms engaged in double bonds have a trigonal planar shape. You will explore this fact by using molecular models in this experiment.

A double bond does not rotate like a single bond. Due to the rigidity in a double bond, the following two structures are not identical even though the atomic connectivity and the molecular formula are the same. Since the double bond between the 2$^{nd}$ carbon and the 3$^{rd}$ carbon atoms does not rotate, the two structures are different molecules even though they have the same molecular formula $C_5H_{10}$. They are called **geometrical isomers** (or ***cis-trans*** **isomers**).





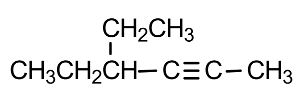
*cis*-2-pentene *trans*-2-pentene

In a *cis*-2-pentene, the methyl group ($CH_3$-) attached to the 2$^{nd}$ carbon is larger than the hydrogen atom attached to the same carbon. For the 3$^{rd}$ carbon atom, the ethyl group (-$CH_2CH_3$) attached is larger than the hydrogen atom. Two larger groups on each side of the double bond are pointing toward the same direction. In a *trans*-2-pentene, two larger groups on each side of the double bond are pointing toward different directions. By using molecular models, you will learn how to identify geometrical isomers.

**3. Alkynes**

Alkynes are hydrocarbons that have at least one triple bond between carbon atoms. Examples are:

$H-C\equiv C-H$



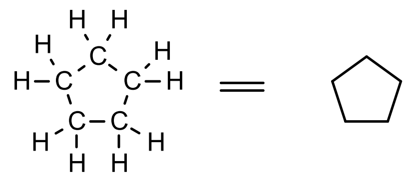
acetylene 4-ethyl-2-hexyne

Carbon atoms engaged in triple bonds have a shape of linear structure around them.

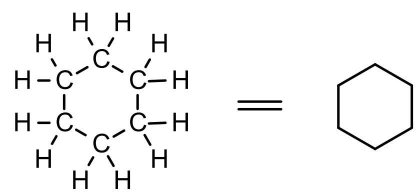
**4. Cycloalkanes and Cylcoalkenes**

Alkanes and alkenes can take a cyclic structure (a ring structure). Examples are:

cyclopentane

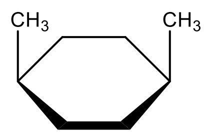


cyclohexane

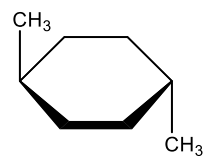


Although the structural formulas and the line angle formulas for cyclopentane and cyclohexane appear planar, their structures are far from being planar. You will build cycloalkanes and explore the actual shapes of these molecules.

Formation of a ring structure prevents free rotations of single bonds in a cyclic structure. Consider the following two structures:



*cis*-1,4-dimethylcyclohexane

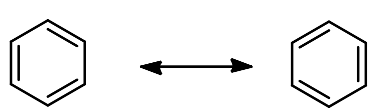


*trans*-1,4-dimethylcyclohexane

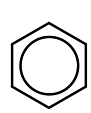
The first molecule cannot be transformed by a rotation of single C-C bonds. Although they have the same molecular formula of $C_8H_{16}$, they are different. These two molecules are **geometrical isomers**. In a *cis*-1,4-dimethylhexane molecule, two methyl groups are pointing toward the same direction while two methyl groups are pointed toward the opposite directions in a *trans*-1,4-dimethylhexane.

**5. Aromatic Hydrocarbons**

Benzene and its derivatives are called **aromatic hydrocarbons**. The structure of a benzene molecule is expressed by using the concept of **resonance**. The following two structures represent equally a benzene molecule:



Notice changes in the positions of double bonds in two structures. Two structures are called **resonance structures**, representing a single structure of a benzene molecule. Instead of using resonance structures, a benzene molecule is often written as



Since all carbons in a benzene ring have a shape of trigonal planar, a benzene molecule is flat. Each carbon atom on a benzene ring has one hydrogen atom, and its molecular formula is $C_6H_6$.

## 6. Isomerism

**Isomers** (**Figure 1**) are molecules that share the same molecular formula, but are different molecules. The objective is to learn to identify isomers along with the reason why they are different (You need to be able to do both).

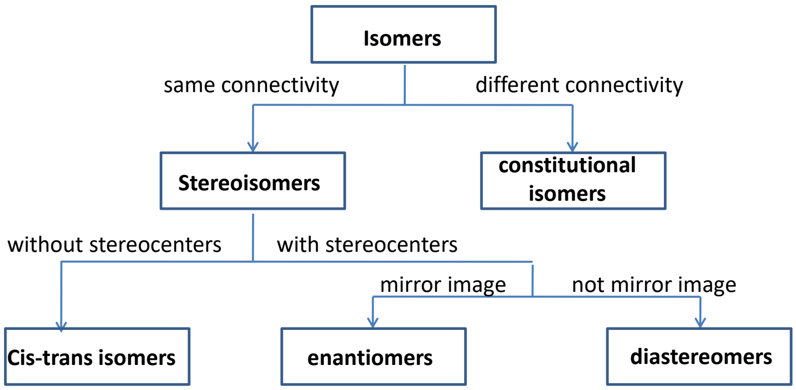
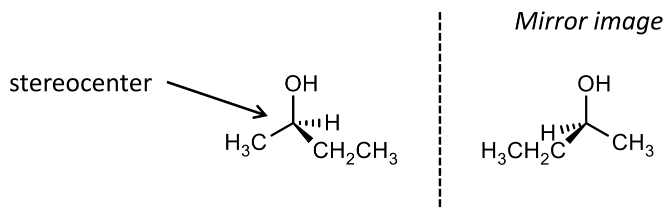



**Figure 1:** Isomerism is summarized. The diagram helps you to decide which types of isomers are present for molecules with the same molecular formula.

Constitutional isomers and *cis-trans* isomers have been explained in previous sections. This section focuses on **enantiomers**.

**Enantiomers**, defined as a pair of molecules that have the same molecular formula, are mirror images to each other, and different molecules. For example, the following enantiomers have the same molecular formula of $C_3H_{10}O$. They are mirror images of each other: The solid line used to indicate the bond is meant to lie on the same plane of the paper. The dotted wedge line is used to indicate the bond points away from you and the bold wedge line is used for a bond pointing toward you. Remember the carbon atom in this example has the shape of tetrahedron.




One characteristic of enantiomers is that a molecule has a carbon atom bearing four different groups. In the example above, four different groups (–OH, $–CH_3$, –H, and $–CH_2CH_3$) attached to the carbon atom pointed by the arrow. A carbon atom with four different groups attached is called a **stereocenter**.

**MATERIALS:** 2 MolyMod molecular model kits

**EXPERIMENTAL PROCEDURE**

When you arrive to lab your TA will give you a handout that will work you through the concepts discussed in the background section. MAKE SURE TO BRING YOUR TEXTBOOK TO LAB, YOU WILL FIND IT VERY USEFUL. No electronic devices will be allowed in the lab for this experiment so if you only have the electronic copy of the text you will need to print the pages you want to use and bring them with you.

You will all work individually in this experiment. If you have any questions, ask the TA. Do not copy any answers from your classmates. You will complete the handout (Lab Report) before you leave the lab. There is no additional Lab report required in Labflow, once you complete the handout in lab you are done with the experiment.

**Hazardous Waste Disposal:** There is no waste generated in this experiment.