FLINN SCIENTIFIC

Name____

Models of Organic Compounds Worksheet

Part A. Models of Alkanes — Structural Isomers

1. Build a model of methane, CH_4, the chief component of natural gas, and draw a diagram that illustrates the three-dimensional structure of the molecule. What is the molecular geometry around the carbon atom in methane?

2. Build models of ethane, C_2H_6, and propane, C_3H_8, and write out their structural formulas.

3. Observe the models: Do the C—C single bonds in ethane and propane rotate freely? Explain.

4. There are two possible structures for butane, C_4H_{10}. Build models of both structures and draw their structural formulas.

5. The two possible structural formulas for butane represent *isomers*. Write a definition of isomers that describes the relationship between these two molecules.

6. Without building models, draw out the possible structural formulas for three isomers of pentane, C_5H_{12}.

7. Alkanes are hydrocarbons—compounds containing only carbon and hydrogen atoms—in which all of the C—C bonds are single bonds. What is the *general formula* for an alkane, where *n* is the number of carbon atoms?

Part B. Models of Alkenes — Geometric Isomers

1. *Alkenes* are hydrocarbons—compounds containing only carbon and hydrogen atoms—that have at least one C=C double bond in their structures. Build models of (a) ethene (C_2H_4) and (b) propene (C_3H_6), and draw their structural formulas.

2. Describe the shape or molecular geometry around the C=C double bond in an alkene. What is the H—C—H bond angle in ethene?

3. Unlike C—C single bonds, C=C double bonds do not rotate. Draw a diagram showing the overlap of the orbitals responsible for the sigma and pi bonds, respectively, in a C=C double bond. Use the orbital diagram to explain why the C=C double bond does not freely rotate.

4. Butene (C_4H_8) has one C=C double bond in the structure. Draw three possible structural formulas for alkenes having the formula C_4H_8. These three molecules represent *isomers*. (See Step 5 in Part A.)

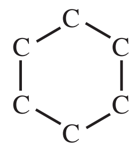
5. The structural formula for *2-butene* can be abbreviated CH_3—CH=CH—CH_3. Because of the lack of free rotation about the C=C double bond (see Step 3), there are two possible structures for this compound. Build models and draw structural formulas for two possible arrangements of the CH_3— groups relative to each other in 2-butene.

6. The two structures for 2-butene shown in Step 5 are called *geometric isomers*. What is the same and what is different about geometric isomers?

7. What is the general formula of an alkene, where *n* is the number of carbon atoms? *Hint:* See the formulas of ethene, propene, and butene. Why do you think alkenes are called unsaturated and alkanes are called saturated hydrocarbons?

Part C. Aromatic Compounds and Resonance

1. Benzene, C_6H_6, is the parent compound of a class of compounds called aromatic compounds that are very common in nature. The carbon "skeleton" for benzene is shown below. Add hydrogen atoms and double bonds, as necessary, to complete the structure of benzene.



2. Build a model of benzene and describe its shape or molecular geometry (planar, tetrahedral, etc.). Are all of the bond angles in benzene identical?

3. The structural formula of benzene shown in Step 1 has alternating single (C—C) and double (C═C) bonds. It has been found, however, all of the carbon–carbon bonds in benzene are identical. This fact may be explained in terms of resonance. Define *resonance* and draw two resonance forms for benzene.

4. Because all of the carbon atoms in benzene are identical, there are three possible structural formulas for dichlorobenzene ($C_6H_4Cl_2$), in which two of the hydrogen atoms in benzene have been replaced by chlorine atoms. Draw structural formulas for the three *isomers* of dichlorobenzene.

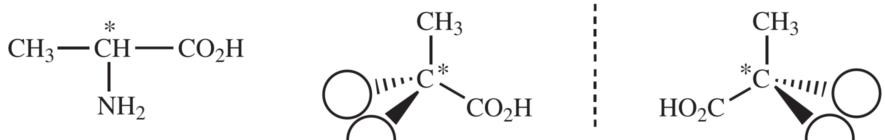
5. How many different structures are possible for trichlorobenzene ($C_6H_3Cl_3$)? Explain.

Part D. Polar Organic Compounds and Biological Molecules

1. Alcohols are organic compounds containing an —OH group attached to a carbon atom. Draw the structural formula of ethyl alcohol, C_2H_5OH.

2. Ethyl alcohol is a polar compound that is miscible with water. As the number of carbon atoms in an alcohol increases, the solubility of the alcohol in water decreases. Thus, octyl alcohol, $C_8H_{17}OH$, is practically insoluble in water. What characteristics of the C_8H_{17}— group make octyl alcohol insoluble in water?

3. Build a model of the amino acid alanine, whose formula is shown below. *Note:* The —CO_2H group has the following bonding arrangement of atoms (—C(=O)—OH).



Alanine *Mirror plane* *Structure A* *Structure B*

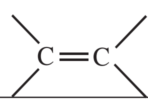
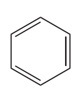
4. Hold the alanine model so that the —CH_3 and —CO_2H groups are in the positions shown in Structure A. Fill in the circles to show the positions of the other two groups (—H and —NH_2) attached to the central (C*) carbon.
5. Complete Structure B so that it represents the mirror image of Structure A. Is it possible to rotate the model of Structure A in your hands so that it matches the mirror-image structure of B? If not, what would you have to do to the some of the bonds in Structure A to make it match Structure B?

6. Structures A and B represent *enantiomers*, which are defined as non-superimposable mirror images of each other. What does it mean to say that enantiomers are *non-superimposable*? Why do you think this property of molecules is sometimes called "handedness?"

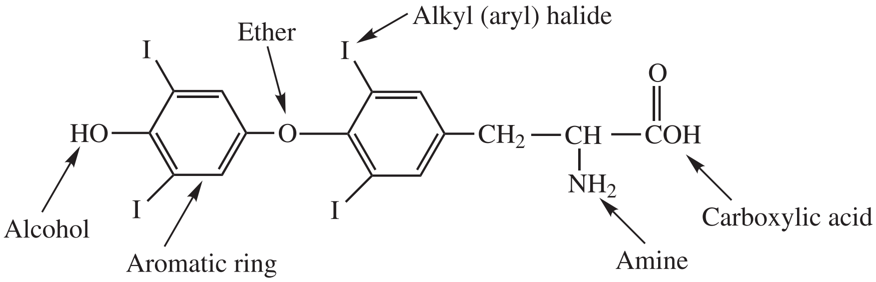
Part E. Organic Functional Groups

Table 1 shows the structures of common organic functional groups. The symbol R is used to represent various rings or chains of carbon atoms attached to the functional group.

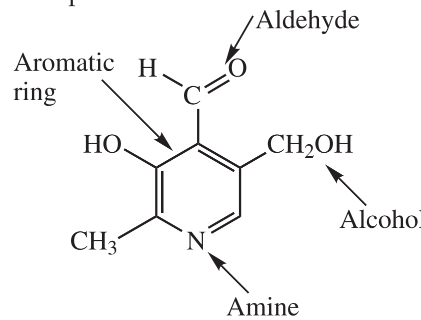
Table 1. Structures of Organic Compounds and Functional Groups

Functional Group	Structure	Functional Group	Structure
Alkenes		**Amines**	R—NH_2 (or R_2NH and R_3N)
Alkynes	—C≡C—	**Ketones**	R—C(=O)—R′
Aromatic Compounds		**Aldehydes**	R—C(=O)—H
Alcohols	R—O—H	**Carboxylic Acids**	R—C(=O)—OH
Ethers	R—O—R′	**Esters**	R—C(=O)—O—R′
Alkyl Halides	R—X (X = F, Cl, Br, I)	**Amides**	R—C(=O)—NH_2

The following examples illustrate the great variety of functional groups present in natural products.



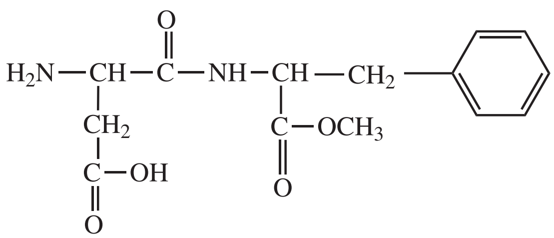
Thyroxine (Thyroid hormone)



Pyridoxal (Vitamin B_6)

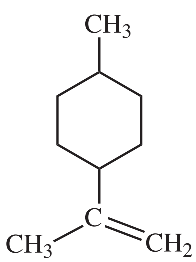
Circle and label the organic functional groups in the following natural and consumer products.

1.



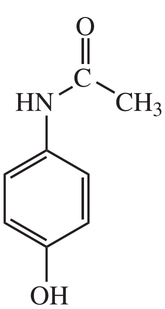
Aspartame (NutraSweet®)

2.



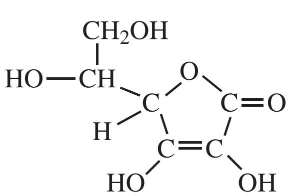
Limonene (Citrus peel oil)

3.



Acetaminophen (Tylenol®)

4.



Ascorbic Acid (Vitamin C)