

Lab 5. Lewis Structures & Model Building

Prelab Assignment

- ⇒ Read this lab handout thoroughly *before* coming to class. Sorry, there are no prelab questions to answer for this activity☹.
- ⇒ This exercise does *not* require a report in your lab notebook. The report for this exercise consists of writing on the attached Report Sheet (pp. 5 – 7) the Lewis structures for the compounds studied (and a few other things too—see the procedure) followed by a summary of what you have learned from this activity.
- ⇒ Bring your textbook to class. It will be handy for looking up the various organic functional groups studied in this activity.

Purpose

In this laboratory exercise you will construct models of various organic compounds, and, from each model, draw the Lewis structure. An important objective of this exercise is for you to begin to learn to visualize the structure and functional groups of organic compounds, and to draw their Lewis structures, without reference to a physical model.

Introduction

A **Lewis structure** is a model used to show the bonding in covalent compounds. In this system, molecular structures are diagrammed by using a line to represent a bonding pair of electrons, and a pair of dots to represent lone (non-bonding) pairs.

A Lewis structure is useful to a chemist because it gives important clues about the three-dimensional structure, physical properties and chemical properties of a compound. You need to be aware that a Lewis structure does not necessarily show the three-dimensional structure of a molecule, and that there are many molecules for which a Lewis structure does not give a complete picture of the bonding environment. More complex models (valence bond theory and molecular orbital theory) have been developed to address the limitations of Lewis structures.

Since the structure of organic compounds is straightforward, and there is a great deal of repetition, drawing the Lewis structures is relatively easy. The bonding rules can be summarized by the following basic rules, which have few exceptions:

- **Carbon** almost always forms 4 bonds (the only common exception is carbon monoxide, CO)
- **Hydrogen** forms only 1 bond (no exceptions)
- **Halogens** (group 7A nonmetals) form 1 bond
- **Oxygen** almost always forms 2 bonds (sometimes 1, e.g. the carboxylate ion, $\text{R}-\text{C}(=\text{O})\text{O}^-$)
- **Nitrogen** almost always forms 3 bonds (sometimes 4, e.g. protonated amines, $\text{CH}_3-\text{NH}_3^+$)

By applying these simple rules, you can deduce the Lewis structure for *almost any* organic compound.

Procedure

You will work with a partner for this exercise.

Obtain a model kit from the lab cart and use it to build molecular models following these guidelines:

1. By convention atoms are represented using the following colors:

Element	Color
Carbon	Black
Hydrogen	White
Oxygen	Red
Nitrogen	Blue
Chlorine	Green
Iodine	Purple

2. Use the short rigid bonds for *single covalent bonds*, and the longer flexible bonds for *double* or *triple covalent bonds*.
3. Fill all of the holes on an atom with bonds. (The exception is nitrogen, which has 4 holes. It will generally form 3 bonds.)

Once you have built a model, draw the Lewis structure for the molecule. Use single lines for single bonds, double lines for double bonds and triple lines for triple bonds. You will need to fill in *the lone pairs* (i.e. nonbonding electron pairs), which are not shown on the model. Add as many lone pairs as necessary to give each atom a complete *octet*.

Part 1 — Simple Organic Compounds

For each formula below, construct a model and draw the Lewis structure of that model in [Table 1](#) on the report sheet. However, *only construct models that have functional groups found in [Table 15.5 on page 4](#)*. Use [Table 15.5](#) (it's a reproduction of [Table 15.5, p. 651, Silberberg 5th ed](#)), to identify each compound or functional group as one of the following: alkane (C_nH_{2n+2}) alkene (C_nH_{2n}), alkyne (C_nH_{2n-2}), alcohol, haloalkane, amine, aldehyde, ketone, carboxylic acid, ester, amide and/or nitrile. Note that there may be more than one possible identification for each compound (i.e. a compound could be both an amine and a carboxylic acid (e.g. an amino acid) and that more than one compound may be possible for each structure below (i.e. it may be possible to make more than one valid structure (isomer) for a given formula). Also note that there are many cyclic organic compounds that form rings with 5 or more carbons.

- | | | |
|----------------|--------------|-----------------|
| 1. CH_3Cl | 4. C_2H_2 | 7. $C_2H_5NO_2$ |
| 2. CH_2O | 5. C_3H_6O | 8. $C_2H_2Cl_2$ |
| 3. $C_2H_4O_2$ | 6. C_6H_6 | 9. C_2H_5NO |

When you have finished drawing each structure be sure to check it by making sure that every element (except hydrogen) has a complete octet of electrons.

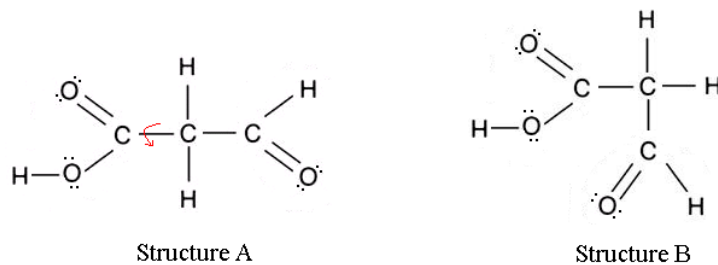
Part 2— Isomers

Organic compounds formed from one set of atoms can often be arranged in more than one way, called isomers. You may have encountered isomers in Part 1, above. Did the person across the table from you come up with a different model for the same compound? Can you both be right? Actually, the answer is “Yes!” You may have each constructed different isomers.

Isomers are defined as two chemical compounds with the same chemical formula, but different structures. They have different physical and chemical properties, and are thus truly different compounds.

1. Construct models of the *two isomers* of C_2H_6O and then draw their Lewis structures in Table 2 of the report sheet. One of the isomers is an **alcohol** (ethanol, commonly found in alcoholic beverages). The other is an **ether** (dimethyl ether), once used as an anesthetic.
2. Construct models of the *three isomers* of C_5H_{12} . Draw the Lewis structures in Table 2.
3. Construct models of and draw Lewis structures in Table 2 of *all possible isomers* of hexane C_6H_{14} . How many are possible? *Be careful here*, for there are fewer than you may think. For example, simply drawing a bond pointing up on the paper instead of down does not represent a different isomer—this you will see very clearly if you make the molecular models!

For example, examine structures A and B to the right. They have the same formula, $C_3H_4O_3$, but are they isomers? The answer is no—they represent the *same* structure of the *same compound* since the **connectivity** of the atoms in each structure is the



same—i.e. the atoms are connected in the same way to one another. It is the ability of the C—C single bond to rotate (shown in structure A with the arrow to the right of the carboxyl group, (—COOH,)) that accounts for the aldehyde group (—CHO) pointing to the right in structure A and downwards in structure B. You will see this clearly if you make a model of structure A and rotate the first C—C single bond to get structure B.

Now compare the structures to the right. Are they isomers?

The answer is yes. Although they have the same connectivity, the inability of the C=C double bond to rotate “locks” the two chlorine atoms into place on the *same* side of the double



double bond in the **cis isomer** and on *opposite* sides of the double bond in the **trans isomer** resulting in two different compounds with different 3-D structures and different chemical and physical properties.

Conclusion

Summarize what you have learned about...

1. Drawing Lewis structures and their relationship to the actual structures of molecules, as represented by the models you constructed.
2. The nature of isomers.

Table 15.5 Important Functional Groups in Organic Compounds

Functional Group	Compound Type	Suffix or Prefix of Name	Example		Systematic Name (Common Name)
	alkene	-ene	$\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C}=\text{C} \\ & / & \backslash \\ \text{H} & & \text{H} \end{array}$		ethene (ethylene)
$-\text{C}\equiv\text{C}-$	alkyne	-yne	$\text{H}-\text{C}\equiv\text{C}-\text{H}$		ethyne (acetylene)
	alcohol	-ol	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array}$		methanol (methyl alcohol)
 (X=halogen)	haloalkane	halo-	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\ddot{\text{X}} \\ \\ \text{H} \end{array}$		chloromethane (methyl chloride)
	amine	-amine	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C} & -\text{C}-\ddot{\text{N}}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$		ethylamine
	aldehyde	-al	$\begin{array}{c} \text{H} & \text{:O:} \\ & \\ \text{H}-\text{C} & -\text{C}-\text{H} \\ \\ \text{H} \end{array}$		ethanal (acetaldehyde)
	ketone	-one	$\begin{array}{c} \text{H} & \text{:O:} & \text{H} \\ & & \\ \text{H}-\text{C} & -\text{C} & -\text{C}-\text{H} \\ & & \\ \text{H} & & \text{H} \end{array}$		2-propanone (acetone)
	carboxylic acid	-oic acid	$\begin{array}{c} \text{H} & \text{:O:} \\ & \\ \text{H}-\text{C} & -\text{C}-\ddot{\text{O}}-\text{H} \\ \\ \text{H} \end{array}$		ethanoic acid (acetic acid)
	ester	-oate	$\begin{array}{c} \text{H} & \text{:O:} & \text{H} \\ & & \\ \text{H}-\text{C} & -\text{C}-\ddot{\text{O}}-\text{C}-\text{H} \\ & & \\ \text{H} & & \text{H} \end{array}$		methyl ethanoate (methyl acetate)
	amide	-amide	$\begin{array}{c} \text{H} & \text{:O:} \\ & \\ \text{H}-\text{C} & -\text{C}-\ddot{\text{N}}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$		ethanamide (acetamide)
$-\text{C}\equiv\text{N:}$	nitrile	-nitrile	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}\equiv\text{N:} \\ \\ \text{H} \end{array}$		ethanenitrile (acetonitrile, methyl cyanide)

Lab 5 Report Sheet
Lewis Structures & Model Building

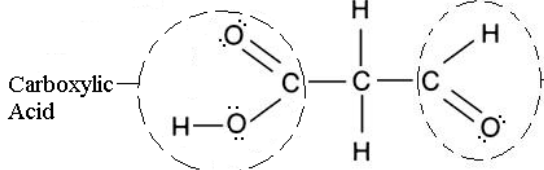
Name _____

Team No. ____ Date _____ Section _____

Experimental Results

Part 1 — Simple Organic Compounds

Table 1. Lewis structures & functional group ID of simple organic compounds

Formula	Lewis Structure (Identify the functional groups)
<p>Example: $C_3H_4O_3$</p>	 <p>The diagram shows the Lewis structure of propanoic acid, CH_3CH_2COOH. The carboxylic acid group ($COOH$) is circled in a dashed line and labeled "Carboxylic Acid". The aldehyde group (CHO) is also circled in a dashed line and labeled "Aldehyde". The central carbon atom is bonded to a methyl group, a hydrogen atom, and the carboxylic acid group.</p>
1. CH_3Cl	
2. CH_2O	
3. $C_2H_4O_2$	
4. C_2H_2	
5. C_3H_6O	

Formula	Lewis Structure (Identify the functional groups)
6. C_6H_6	
7. $C_2H_5NO_2$	
8. $C_2H_2Cl_2$	
9. C_2H_5NO	

Part 2 — Isomers

Table 2. Lewis structures of all isomers of three simple organic compounds

Formula	Lewis Structure of all Isomers
1. C_2H_6O	

Formula	Lewis Structure of all Isomers
2. C_5H_{12}	
3. C_6H_{14}	

Conclusion
