

Lab Activity H6

Molecular Models

OUTCOMES

After completing this lab activity, the student should be able to:

- differentiate between molecular compounds and ionic compounds.
- identify the correct three-dimensional model of a molecular compound given a molecular formula.
- construct a Lewis diagram given a molecular formula and/or three-dimensional molecular model

DISCUSSION

A chemical bond is a force of attraction that holds atoms together in compounds. Bonds form to attain a more stable arrangement of valence electrons. Chemical bonds may be either ionic bonds or covalent bonds. An ionic bond results from the transfer of valence electrons from metal atoms to nonmetal atoms and the subsequent attraction of oppositely charged particles, while the covalent bond results from the sharing of valence electrons between two nonmetal atoms.

By the time you get to this lab activity, you should have already discussed chemical bonds in general and ionic bonds. You should be familiar with the *octet rule*. What is the octet rule? In this lab activity, we will only consider molecular compounds. Molecular compounds are comprised of molecules. A molecule is a group of atoms (usually only nonmetals) held together by covalent bonds. If these terms are unfamiliar, please read about them in your Chemistry 1020 textbook before this lab activity.

One of the disadvantages of constructing Lewis (electron dot) diagrams on paper is that little information can be obtained about the three-dimensional geometry of a molecule. The geometry of a molecule provides important information about the physical and chemical behavior of a molecule and the compound as a whole. The chemical behavior due to its geometry is often left for study in upper level chemistry classes. Using the models, you will examine the three-dimensional structure of the carbon atoms in many of the molecules in this lab activity. Your lecture instructor may elect to relate this lab activity to geometry and polarity later in the course, so hold on to this lab activity.

While this is the same lab activity that is being performed by the on-campus students, it differs in that on-campus students will be using wood or plastic molecular model kits to construct three-dimensional molecular models, while this activity uses virtual molecular models. However, the net result should be the same – you should be able to construct Lewis diagrams after completion of this lab activity.

PROCEDURE

Record the letter of your assigned molecular model set at the top of the first data page. Then, go to <http://webs.anokaramsey.edu/chemistry/online/1020/models> and click on the letter of the molecular model set you were assigned. Each set has a total of 40 molecular models, presented on 5 different pages with 8 models per page. It should be noted that only 28 of these models are correct and 12 of the models are incorrect. It will be up to you to determine which models are correct, based on bonding rules you have learned. **REQUIRED PHOTO:** Includes the date clearly shown on a calendar, newspaper, cell phone, or written on a sheet of paper, along with the laminated card that shows your assigned molecular model set and models from your set shown on your computer screen.

All of the molecular models in this lab are rendered using Jmol java applets. It will take several seconds to load the Jmol applet the first time, or up to a minute or more if your computer or internet connection is slow. Subsequent models will load much faster. Java is ordinarily enabled on web browsers. In the event it is not, you will need to enable Java and/or download the latest version for your operating system. The free download and instructions may be found at <http://java.com/en/download/index.jsp>.

The atoms are color coded to represent different elements as follows:

Element	Symbol	Color
Hydrogen	H	White
Carbon	C	Grey
Oxygen	O	Red
Nitrogen	N	Blue
Chlorine	Cl	Green

Element	Symbol	Color
Iodine	I	Purple
Bromine	Br	Brown
Phosphorus	P	Orange
Sulfur	S	Yellow

In the event you have difficulty with colors, move the pointer above an atom and the atomic symbol for that element will be displayed after about two seconds, along with that atom's numbered position in the molecule.

Each ball represents an atom, while each stick between two atoms represents a covalent bond. Therefore, if two atoms are joined by a single stick, the stick represents a single covalent bond (simply referred to as a single bond) comprised of two shared electrons. If two atoms are joined by two sticks, the connectors represent a double bond and a total of four shared electrons. If two atoms are joined by three sticks, the connectors represent a triple bond and a total of six shared electrons. Finally, the total number of sticks coming out of each atom indicates the number of bonds that atom forms in the given molecule.

There are three check boxes associated with each of the molecular models on each page. Checking the box that reads "sticks" will cause only the sticks (or bonds) to be displayed. Removing the check will bring the atoms back. Checking the box that reads "zoom in" will enlarge the molecule to fill the box. Removing the check will return the model to its original size. Checking the box that reads "spin molecule" will spin the molecule along the horizontal axis.

Molecular models rendered with Jmol may also be rotated in any direction by clicking on a model while holding down the left mouse button and dragging in the desired direction. Zooming in or out on a given molecule may be accomplished two different ways. One way is to click on a model and rolling the scroll wheel on the mouse back and forth. The other way is to hold down the shift key while pressing the left mouse button and dragging your mouse forward or back. Jmol also has many other options that are available, but unnecessary for this lab. If desired, other options may be explored by pointing at a molecular model and holding down the right mouse button. A menu of different choices will be displayed.

For each molecular formula given in (a)-(y),

1. Locate the correct model for the given molecular formula from your assigned set of 40 structures. Each formula has only one correct answer. As stated earlier, 12 of the 40 structures are incorrect. There may be more than one structure with the correct number of atoms, but without the correct number of bonds. Therefore, pay close attention to both the number of atoms AND number of bonds in each model. Once the correct structure has been identified, record its structure number in the appropriate column on your data page.
2. Draw Lewis (electron-dot) diagrams for each compound in your report. Use lines to represent shared electron pairs and dots to represent unshared electron pairs. **The Lewis diagram drawn should reflect the actual shape of the molecule.** While the shapes need not be drawn perfectly,
 - Do **not** draw a linear molecule if the molecule clearly has a bent shape.
 - Do **not** draw a bent molecule if the molecule is clearly linear.
3. For simple neutral molecules like those in this lab activity, three simple checks will ensure that your Lewis electron-dot diagram is correct. For each diagram, place a check mark in the appropriate box in the rightmost columns once you've checked the following:
 - a. **The correct number of valence electrons are shown in your completed electron-dot diagram.** Count the number of valence electrons shown in your diagram (remembering that each covalent bond is a pair of electrons). This should match your calculated total. (This rule applies to *all* electron-dot diagrams.)
 - b. **The octet rule or duet rule is followed in every atom in your diagram.** You should be able to count 8 electrons (including bonds) around all atoms (except hydrogen, which should have 2). (Note, your instructor may introduce you to some molecules that do not obey the octet/duet rule, but the rule does apply to all molecules in this lab activity.)
 - c. **Every atom in your diagram has the correct number of bonds.** To make the best electron-dot diagrams, atoms should have only the number of bonds necessary to fill their octet. For instance, chlorine has 7 of its own valence electrons, so it should only form 1 covalent bond. (Note, if you draw diagrams of polyatomic ions in lecture, this rule does not necessarily apply to them. This rule applies to simple *neutral* molecules like those in this lab activity.)

4.1. Molecules of these substances have only **single bonds**.

- | | | | |
|----------------------|---------------------|---------------------------------------|---------------------------------------|
| (a) H ₂ | (e) NH ₃ | (i) PCl ₃ | (l) H ₂ O ₂ |
| (b) H ₂ O | (f) HOCl | (j) CH ₂ Cl ₂ * | (m) CCl ₄ * |
| (c) HCl | (g) I ₂ | (k) CH ₄ * | (n) CH ₃ NH ₂ * |
| (d) SCl ₂ | (h) BrCl | | |

4.2. Molecules of these substances have **double bonds**. There may be more than one double bond present.

- | | | |
|-------------------------|-------------------------------------|------------------------------------|
| (o) O ₂ | (q) C ₂ H ₄ * | (s) COCl ₂ |
| (p) CH ₂ O * | (r) CO ₂ * | (t) H ₂ CO ₃ |

4.3. Molecules of these substances have **triple bonds**.

- | | | |
|--------------------|-------------------------------------|-----------|
| (u) N ₂ | (v) C ₂ H ₂ * | (w) HCN * |
|--------------------|-------------------------------------|-----------|

4.4. The following compounds have **isomers**. Isomers are compounds that have the same molecular formula, but different molecular structures. Since your experience with three-dimensional molecular models is limited, it is important that you carefully examine all of the available models in your assigned model set to confirm your answers. Keep in mind that 12 of the 40 provided structures are incorrect.

- (x) C₄H₁₀ (2 isomers possible. Give both.)
(y) C₂H₂Cl₂ * (3 isomers possible. Give all three.)

4.5. *Optionally, your instructor may ask you to investigate the geometry of the carbon atoms in certain molecules in this lab activity. For the starred compounds, determine the geometry of carbon in the compound:

- Carbon has a **tetrahedral geometry** when it is connected to four atoms, all by single bonds.
- Carbon has a **trigonal planar geometry** when it is connected to three atoms, one by a double bond and two by single bonds (this is the only way carbon can be attached to three atoms but still contain a total of four covalent bonds).
- Carbon has a **linear geometry** when it is connected to two atoms, either with two double bonds or one single and one triple bond.

As you are examining the models, look at the position of the atoms connected to the carbon atoms in the starred compounds and be sure you understand the differences between these three geometries. Your instructor may ask you to draw your Lewis structures with the correct carbon geometry shown.

Name _____

Lab Section _____

PRELAB QUESTIONS

1. Complete the following table:

Element:	H	C	N or P	O or S	F, Cl, Br, or I
Group number:					
Number of valence electrons:					
Normal number of covalent bonds:					

2. What is the octet rule?

3. What are some differences between atoms, ions, and molecules?

4. Which bonds are found within molecules? How are these bonds formed?

PHOTOS - Please compress photos and save your file **before** uploading to the dropbox. Photos should come close to filling the boxes below and all required items should be **clearly visible**.

Required Photo 1:

Required Photo 2:

Name _____

Lab Section _____

Assigned Molecular Model Set _____

Formula	Sum of valence e ⁻	Structure Number	Lewis Diagram	All valence e ⁻ shown?	All atoms follow octet or duet rule?	Correct # bonds per atom?
(a) H ₂				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(b) H ₂ O				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(c) HCl				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(d) SCl ₂				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(e) NH ₃				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(f) HOCl				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(g) I ₂				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(h) BrCl				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Name _____

Lab Section _____

Formula	Sum of valence e ⁻	Structure Number	Lewis Diagram	All valence e shown?	All atoms follow octet or duet rule?	Correct # bonds per atom?
(i) PI_3				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(j) CH_2Cl_2^*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(k) CH_4^*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(l) H_2O_2				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(m) CCl_4^*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(n) CH_3NH_2^*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(o) O_2				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(p) CH_2O^*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Name _____

Lab Section _____

REQUIRED PHOTO: Includes your face and/or clearly shows a Picture I.D. (with name), with approximately half of your Lewis diagrams completed, either on the screen and/or on a sheet of paper.

Formula	Sum of valence e ⁻	Structure Number	Lewis Diagram	All valence e ⁻ shown?	All atoms follow octet or duet rule?	Correct # bonds per atom?
(q) C ₂ H ₄ *				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(r) CO ₂ *				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(s) COCl ₂				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(t) H ₂ CO ₃				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(u) N ₂				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(v) C ₂ H ₂ *				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(w) HCN*				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Name _____

Lab Section _____

Formula	Sum of valence e ⁻	Structure Number	Lewis Diagram	All valence e ⁻ shown?	All atoms follow octet or duet rule?	Correct # bonds per atom?
(x) C ₄ H ₁₀				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(y) C ₂ H ₂ Cl ₂ *				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Lab Report Submission Checklist

Complete the appropriate checklist and **submit this page** along with your lab activity.

Lab Activity Submitted Via the D2L Dropbox

	Prelab assignment is complete.
	Remainder of lab activity is complete (data, questions, photos. etc.).
	Minimum of two photos of different parts of the procedure included.
	At least one photo shows face or photo I.D. At least one photo clearly shows the date.
	Document filename in format of Lastname Firstname HX .
	File size is no larger than 10 MB.
	Only one document submitted for this lab activity.
	Lab submitted on time.
	If late, this is your first extension.



Lab Activity Submitted Via the US Postal Service or In Person

	Prelab assignment is complete.
	Remainder of lab activity is complete (data, questions, photos. etc.).
	Minimum of two photos (at least one showing face or photo I.D.; at least one shows the date) of different parts of the procedure or a tangible artifact or product from the lab activity is included.
	If return is desired, a self-addressed stamped envelope with sufficient postage is included*.
	Lab submitted on time (postmarked by due date if sent via USPS).
	If late, this is your first extension.

*You may find a postage calculator at <http://postcalc.usps.gov>. Use the balance in your kit to find the weight.