Introductory Chemistry Laboratory: Chemical Bonding

Outcomes

As a result of today's laboratory, you will have:

Viewed a program about chemical bonding and completed a viewing guide.
Built models of chemical compounds with model kits.
Completed a survey to provide feedback about the experiments performed this semester.

Prelab

Prepare a Title (can use the lab handout for this), Purpose (a concise statement) and a Procedure (short "to do" list … see "Writing a Procedure" in the lab handouts folder). **Complete the lab survey.**

Purpose

To observe models of ionic and covalent compounds and to predict their molecular shape and polarity.

Background Information

Chemical bonds are attractive forces that hold atoms together. The common types of chemical bonding are ionic, covalent, and metallic. These types of chemical bonding are used to explain the properties we observe for ionic or covalent compounds and metals.

In ionic bonding, the outermost (valence) electrons are transferred from the more electropositive (donating electrons) elements (found on the left of the periodic table) to the more electronegative (accepting electrons) elements (found on the right of the periodic table). The force that holds the compound together is the electrostatic attraction between the positively charged cation and the negatively charged anion. Ionic compounds do not exist as individual combined units (molecules). The three dimensional shape of the ionic compound is determined by the relative sizes of the positive and negative ions that make up the compound, In solids, the ions pack together in layers. The layers extend to form a crystal. The unit cell is the smallest part of the crystal, which can be extended in all directions to generate the entire crystal.

In covalent bonding one or more pairs of valence electrons are shared between two non-metallic elements (found on the right of the periodic table). The three dimensional shape of a covalent molecule is determined by the directionality of the regions in space in which the shared valence electrons are found and by the number of bonds formed to make the compound.

In polar covalent bonding, one of the elements has a greater ability to attract the shared electrons in the covalent bond. The molecule formed is a dipole. It has a positive end and a negative end. Molecules of a polar covalent compound will be attracted to other molecules. We call these forces between molecules intermolecular forces. Intermolecular forces have a profound effect on compound properties.

In metallic bonding, the valence electrons are delocalized. If there were an electron-accepting non-metal available, the valence electrons of the electron-donating metal would be transferred. Since there is no electron acceptor, the electrons are loosely held and relatively free to move throughout the sample. The force that holds the atoms in a metal together is stronger than that found between molecules and weaker than the electrostatic attractions between ions.

Procedure

Part I. Exploring Metallic Bonding using the Metal Model

In a metallic bond (example copper-copper), the electrons don't have a fixed position and can move around between nuclei. Look at the model of a metal in the black box. The larger white spheres represent the nucleus and inner electrons of individual metal atoms. The smaller beads represent the outer **(valence)** electrons associated with each nucleus. Using the Metal Model, move the box back and forth. Describe the electron motion in your lab notebook.

Part II. Observing a model of an ionic compound (Work in Groups)

Copy Table 1 in your lab notebook and fill in the cells of the table.

1. Observe the model of the sodium chloride (NaCl) crystal.
2. Describe its shape.
3. Are there any independent units or molecules of NaCl?
4. What is the ratio of number of Na^{+} to Cl^{-} ions?

Part III. Building models of covalent molecules (Work in pairs)

A model kit contains colored spheres to represent different atoms and rigid short bonds and long flexible bonds to represent shared pairs of electrons. The spheres are drilled with holes to represent the correct number of bonds and the bond angles. Color codes for the different elements are given in the table below. Copy this table into your lab notebook and fill out the information as directed below.

1. Examine each of the different spheres.
2. Count the holes in each and record the numbers of bonds that can be formed by each.

Rules for constructing molecular models:

The color code tells you which sphere to use.
The subscripts of the chemical formula tell you how many of the atoms to use.
All bonds (holes) must be used
Use rigid sticks for single bonds (one shared pair of electrons).
Use flexible sticks for multiple bonds.
Carbon, Nitrogen, and oxygen easily form multiple bonds.

Construct each of the covalent molecules listed in Table 3. Sketch the molecule, record its molecular shape (see below) and infer the polarity of the molecule.

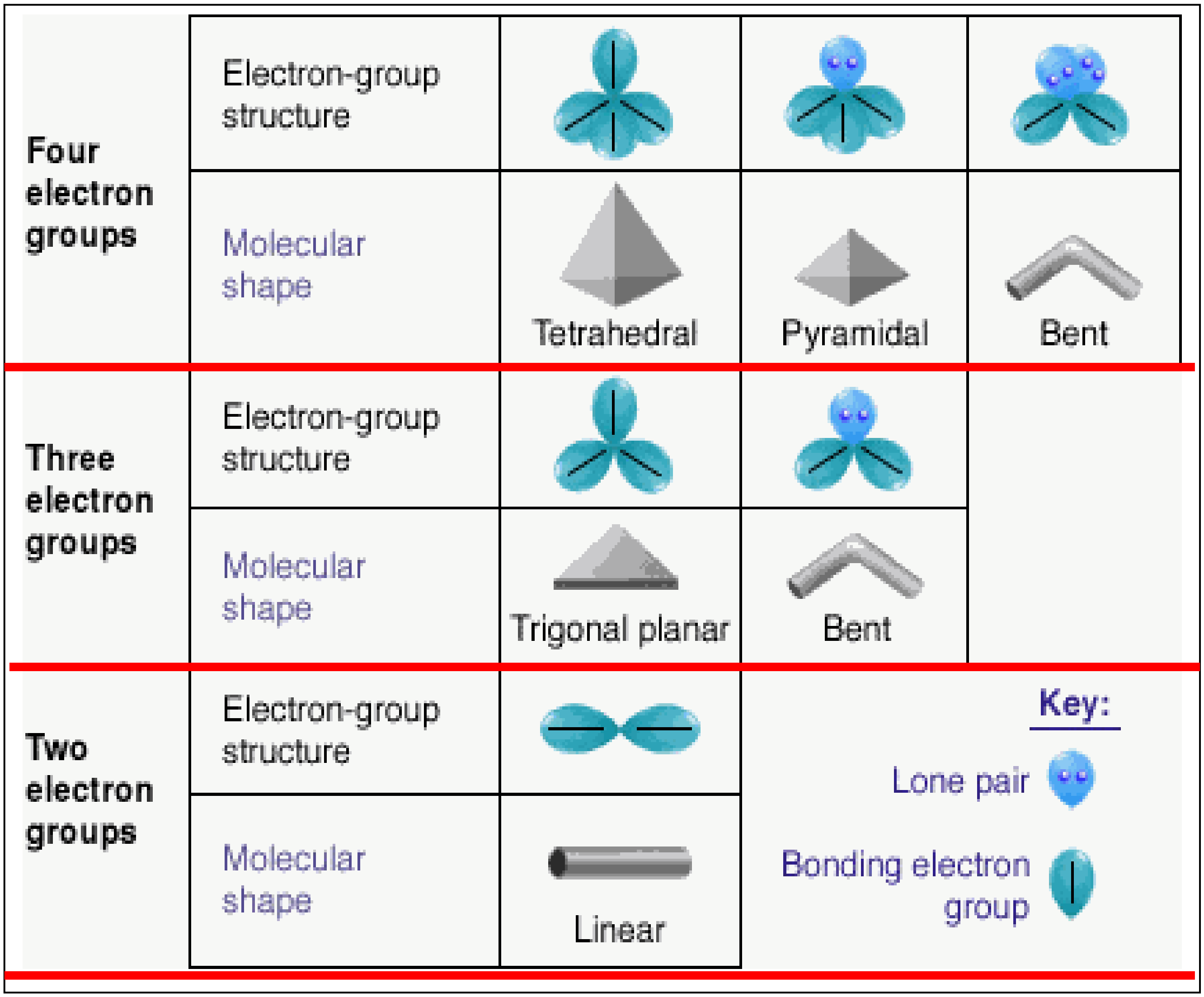
For the **sketch,** ball and stick drawings are OK.
For the **shapes,** the key is below.
For the **polarity,** look at the molecular model. Is it symmetrical (looks the same when viewed from all exterior atoms towards the central atom)? If so, the molecule is non-polar. If it is not symmetrical, then it would be Polar. (Example: H_2O is polar; CCl_4 is non-polar)

The simple shapes below are best used for simple molecules having only one central atom. With organic molecules, there is no single description for the entire molecule since each carbon atom can have a different shape. For example, ethylene (C_2H_4) is a planar molecule, but each of the two carbon atoms has a trigonal planar shape,

Determining Molecular Shape

Count the number of electron groups (either bonds or unshared pairs)
Determine molecular shape from the following chart

Molecular Shapes



Data

Table 1: NaCl Model

Shape	Independent Unit (Yes or No?)	Ratio Na^+ to Cl^-

Table 2: Atom Color Codes and Bonds

Element	Symbol	Color	# of bonds	Element	Symbol	Color	# of bonds
Hydrogen	H	white		Nitrogen	N	Blue	
Chlorine	Cl	green		Oxygen	O	Red	
Carbon	C	black					

Table 3: Covalent Molecules

Molecule	Formula	Sketch	Shape	Polarity
oxygen	O_2			
nitrogen	N_2			
carbon dioxide	CO_2			
methane	CH_4			
water	H_2O			
ammonia	NH_3			
carbon tetrachloride	CCl_4			
carbon monoxide	CO			
ethane	C_2H_6		*	
ethene (ethylene)	C_2H_4		planar	
ethyne (acetylene)	C_2H_2		linear	
propane	C_3H_8		*	
butane	C_4H_{10}		*	

* Simple shapes are most relevant for simple molecules. Since many organic molecules have multiple conformations, this parameter is commonly not applicable to multiple carbon-containing molecules.

Conclusion

Summarize the different types of bonds (metallic, ionic, non-polar covalent, and polar covalent) studied during this experiment. What is the primary difference between ionic bonds and covalent bonds? What shapes did you encounter?

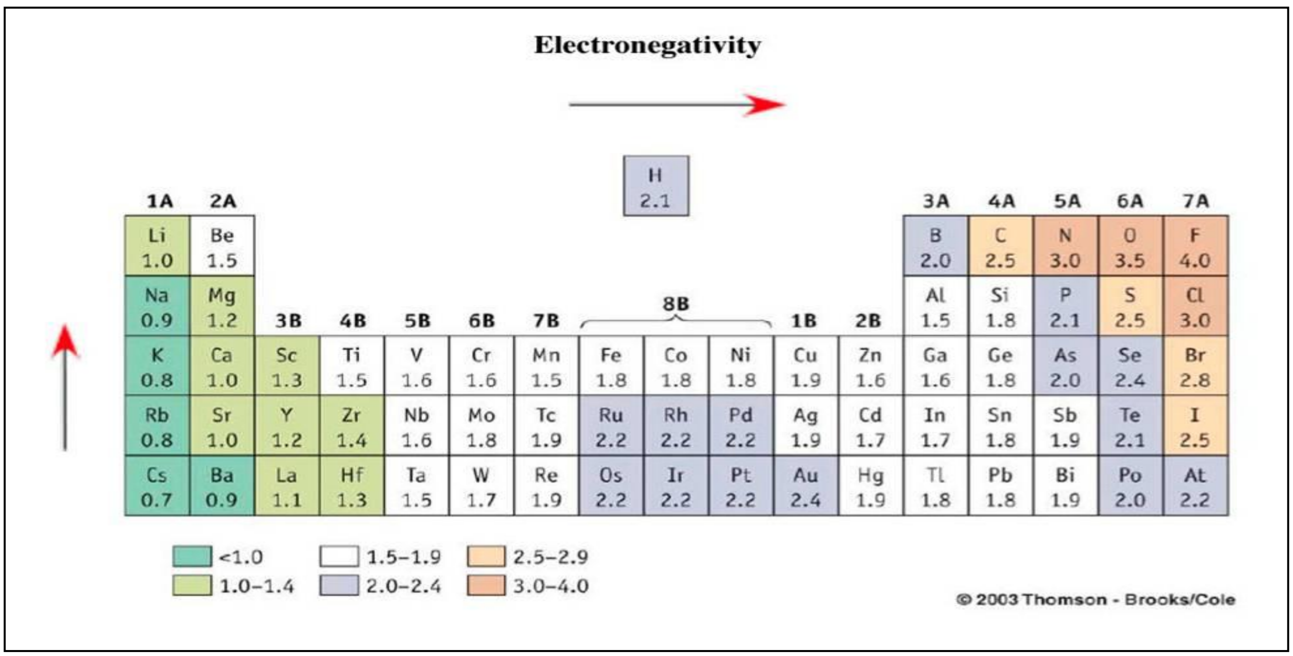
Clean-Up

Molecular modeling is no fun when the appropriate components are missing. To assist other students, please count your components and return the kit to the hood with the following:

4 carbon atoms	(black)
10 hydrogen atoms	(white)
4 chlorine atoms	(green)
2 oxygen atoms	(red)
2 nitrogen atoms	(blue)
2 sulfur atoms	(yellow)
2 metal atoms	(silver … not present in every kit)
20 single bonds	(short, rigid connectors)
6 double bonds	(long, flexible connectors)

Questions

1. Do the covalent molecules you constructed exist as independent units? Explain.
2. List the advantages and disadvantages of using ball-and-stick models to construct molecules.
3. Use the chart below to calculate the electronegativity difference (**Δ EN)** and predict the bond type



Δ ≤ 0.4 ➔ non-polar covalent

Δ > 0.4 - 1.9 ➔ polar covalent

Δ > 1.9 ➔ ionic

Δ = difference in electronegativity of the bonded atoms

4. Complete the table

Atoms	Electronegativity difference (Δ EN)	Type of bond
Na-Cl		
C-Cl		
S-O		
N-N		

5. Which bond is least polar? Which bond is most polar?

   a. H-O
   b. H-S
   c. H-P
   d. H-C

6. Based on your observations of the Metal Model, account for the electrical conductivity of metals.