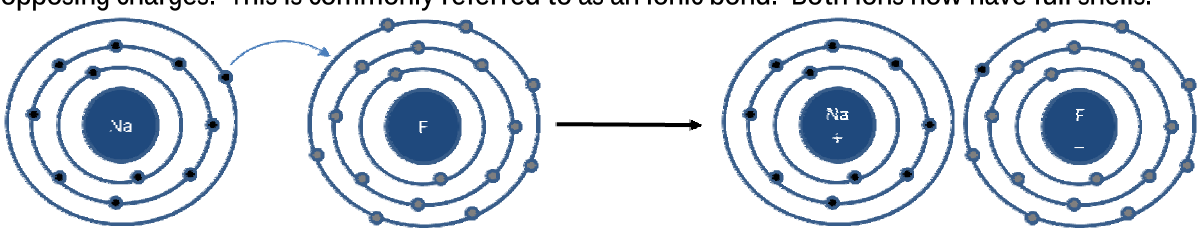
MOLECULAR SHAPES AND LEWIS DOT STRUCTURES MODELING LAB

Purpose: Electrons are the negatively-charged particles that move around the nucleus of an atom and are responsible for the bonding of one atom to another. The bonding of different combinations of atoms gives us a virtually unlimited number of molecules. This lab will help you visualize the actual shapes of molecules, not just the letter representations we use to write them in our notes and textbooks. This is a dry lab, meaning we won't be using any chemicals.

Background: Typically an atom will use only the electrons in its outer shell, called the valence electrons, to form bonds with other atoms; the interior shells remain intact during reactions. To be the most stable, atoms need to have full shells. For many elements, an *s* subshell, which fits 2 electrons, and *p* subshell, which fit 6 electrons, make up the outer shell. For a stable structure, these elements need to have a total of 8 electrons in the outer shell, also called an "octet". Exceptions include hydrogen and helium, which only have an *s* subshell in the outer shell and are thus stable with only 2 electrons, and elements with a *d* subshell can fit up to 18 electrons. If you draw the electron configuration for any of the noble gases, you can see that they all have full outer shells. This full shell keeps these atoms "happy" and thus they don't readily react with other atoms to form new molecules. For all other elements in the periodic table, there is space in the outer shell that can still fit electrons. There are two ways atoms can fill these shells.

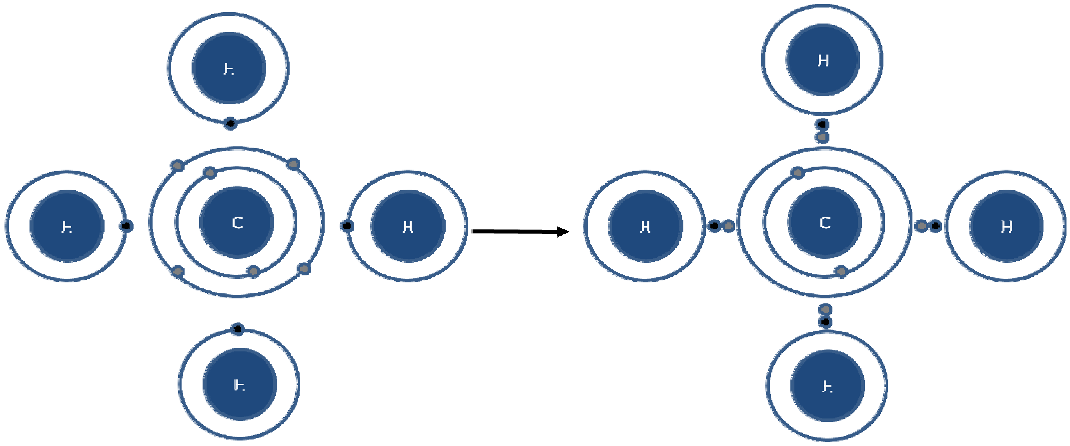
An atom with an almost full shell (think of elements in groups 6, 7, and 8) can steal enough electrons from an atom with an almost empty shell (think of elements in groups 1 and 2) to fill its outermost shell; the atoms become ions and form an ionic bond. They will be attracted to each other by opposing charges (Figure 1).

Figure 1: Depicting the loss of an exterior electron from sodium to an almost full shell on fluorine to create sodium fluoride. The result is a sodium cation and a fluorine anion, which are held together by opposing charges. This is commonly referred to as an ionic bond. Both ions now have full shells.



The second way an atom can fill its outermost shell is by sharing electrons with another atom. This happens most commonly in elements with nearly full outer shells reacting with each other, primarily hydrogen and the non-metals in groups 3 through 7. The result is a covalent bond. Neither atom alone has a full outer shell, but by combining electrons, they both do and become quite stable. For now you can think of the shared electrons as being between both atoms' nuclei, and count both shared electrons for each atom it is between (basically, double dipping on the electron count) (Figure 2). In actuality, the process of bonding creates new molecular orbitals for them to sit in.

Figure 2: Depicting the sharing of electrons that can occur between four hydrogen atoms and a carbon atom to form the chemical methane. All 8 electrons around carbon get counted for carbon, and each hydrogen has two.

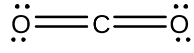


It is helpful for chemists to be able to predict how atoms will form covalent bonds with other atoms and what the resulting molecules will look like. We first need to start out by determining the valence electron count. To figure out the valence of an atom, you must write out the electron configuration. For example, in carbon dioxide, CO_2, we have carbon and oxygen. The electron configurations for these are:

Carbon: $1s^2 2s^2 2p^2$
Oxygen: $1s^2 2s^2 2p^4$

Looking at carbon, we can see that the outer shell (the coefficients in the $2s^2 2p^2$ part) has 4 electrons in it (look at the superscripts). It needs four electrons to fill its outer shell. It can get these electrons by sharing with other atoms to fill its octet. Therefore, carbon needs to form 4 bonds. Oxygen, on the other hand, has 6 electrons in its outer shell and only needs to form two bonds to fill its octet. All four electrons will be involved in bonding with the carbon, but only two will for oxygen. In essence, however many electrons an atom needs will equal the number of bonds it makes. The other 4 electrons in oxygen that don't need to be shared will not be involved in bonding. They will remain in their orbitals as "lone-pair electrons", that is, electrons that are not involved in bonding, but are in the outermost shell.

We can use a puzzle-piece approach to predict structure, using what you already know to come up with an accurate structure for a variety of molecules. For example, if you know that carbon dioxide has one carbon and two oxygens, and carbon needs 4 total bonds, and oxygen needs two total bonds each, we can draw CO_2 as follows:



This type of structure is called a Lewis dot structure (named after the chemist that developed them). Each line represents two electrons and the dots are lone pair electrons not involved in bonding. Once a Lewis dot structure has been drawn, making a model depiction of the molecule is quite easy.

Equipment: A molecular modeling kit with the following color balls; black with 4 holes (carbon), red (oxygen), blue with 4 holes (nitrogen), green (halogen), and white (hydrogen). Single bonds are straight, whereas double and triple bonds used the blue curved bonds. The flat disks can be used to indicate a lone pair of electrons (where each disk is two electrons).

Procedure:

Use the following rules when assigning bonds to atoms:

1. *Don't break the valence of the atom, that is, don't put in more bonds or lone pair electrons than it needs to fill an octet. Most model kits are full proof, in that only so many bonds can fit around an atom.*
2. *You can add single, double, or triple bonds between atoms, but no more.*
3. *Hydrogen only needs two electrons, not a full octet, and no lone pair electrons*

I. Oxygen structure determination:
   a. Draw on the data sheet an oxygen atom with two single bonds and an oxygen atom with a double bond. Include the two lone pair electrons.

II. Carbon structure determination:
   a. Draw on the data sheet a carbon atom with four single bonds, one with two double bonds, one with a double bond and two single bonds, and one with a triple bond and single bond.

III. Nitrogen structure determination
   a. Draw on the data sheet a nitrogen atom with a triple bond, one with a double bond and single bond, and one with three single bonds. Include lone pair electrons.

IV. Chlorine structure determination
   a. Draw on the data sheet a chlorine atom with a single bond. Include lone pair electrons.

V. Fluorine structure determination
   a. Draw on the data sheet a fluorine atom with a single bond. Include lone pair electrons.

VI. Bromine structure determination
   a. Draw on the data sheet a bromine atom with a single bond. Include lone pair electrons.

VII. Hydrogen structure determination
   a. Draw on the data sheet a hydrogen atom with a single bond.

VIII. Combining components
   a. Use the model kit to form the following molecules and draw your results on the data sheet. Remember to follow the rules you established for how many bonds and lone pair electrons will be found around each atom. Use the puzzle pieces you drew in I-VII to fit the atoms together. After you make each of the models, sketch out the molecule using a Lewis-dot structure. Keep the angles between the atoms representative of what you see in the model.
      i. C_2H_6—ethane
      ii. H_2O_2—peroxide
      iii. CH_4—methane
      iv. NH_3—ammonia
      v. CH_2O—formaldehyde

vi. $CHCl_3$—chloroform
vii. H_2O—water
viii. CH_4O—methanol
ix. CH_5N—methylamine
x. Br_2—bromine gas
xi. N_2—nitrogen gas
xii. C_3H_8—propane
xiii. C_2F_4—tetrafluoroethylene
xiv. CH_2Cl_2—methylene chloride
xv. C_2H_2—acetylene gas
xvi. HCN—hydrocyanic acid
xvii. HF—hydrofluoric acid
xviii. $COCl_2$—phosgene

MOLECULAR SHAPES AND LEWIS DOT STRUCTURES MODELING PRE-LAB

Name:____

OXYGEN:

1. Electron configuration: ______________________________
2. Valence electrons: ______________________________
3. Electrons needed to form an octet: ______________________________
4. Bonds needed: ______________________________
5. Lone pairs: ______________________________

CARBON:

6. Electron configuration: ______________________________
7. Valence electrons: ______________________________
8. Electrons needed to form an octet: ______________________________
9. Bonds needed: ______________________________
10. Lone pairs: ______________________________

NITROGEN:

11. Electron configuration: ______________________________
12. Valence electrons: ______________________________
13. Electrons needed to form an octet: ______________________________
14. Bonds needed: ` ______________________________
15. Lone pairs: ______________________________

CHLORINE:

16. Electron configuration: ______________________________

17. Valence electrons: ____________________

18. Electrons needed to form an octet: ____________________

19. Bonds needed: ____________________

20. Lone pairs: ____________________

BROMINE:

21. Electron configuration: ____________________

22. Valence electrons: ____________________

23. Electrons needed to form an octet: ____________________

24. Bonds needed: ____________________

25. Lone pairs: ____________________

FLUORINE:

1. Electron configuration: ____________________

2. Valence electrons: ____________________

3. Electrons needed to form an octet: ____________________

4. Bonds needed: ____________________

5. Lone pairs: ____________________

HYDROGEN: ____________________

6. Electron configuration: ____________________

7. Valence electrons: ____________________

8. Electrons needed: ____________________

9. Bonds needed: ____________________

10. Lone pairs: ____________________

MOLECULAR SHAPES AND LEWIS DOT STRUCTURES MODELING DATA SHEET

Name:____

Partner's name:__________________________________

PUZZLE PIECES:

OXYGEN:

CARBON:

NITROGEN:

CHLORINE:

BROMINE:

FLUORINE:

HYDROGEN:

LEWIS-DOT STRUCTURES

ETHANE	PEROXIDE	METHANE
AMMONIA	FORMALDEHYDE	CHLOROFORM
WATER	METHANOL	METHYLAMINE
BROMINE GAS	NITROGEN GAS	PROPANE
TETRAFLUOROETHYLENE	METHYLENE CHLORIDE	ACETYLENE GAS
HYDROCYANIC ACID	HYDROFLUORIC ACID	PHOSGENE