What Makes a Molecule?

Why are we doing this?

The properties of a molecule depend on how electrons are distributed in the molecule. For example, it takes more energy to separate an oxygen atom from a carbon atom in a molecule of carbon monoxide, CO, than it does to separate an oxygen atom from a carbon atom in carbon dioxide, CO_2. Another example, CO_2 is a linear molecule (the three nuclei lie in a straight line), whereas H_2O is not linear (the three nuclei do not lie in a straight line). These experimentally determined facts can be predicted by making diagram s of molecules, called Lewis structures. The purpose of Lewis structures is to provide a simple way for chemists to represent molecules that allows reasonable predictions to be made about the structure and properties of the actual molecules.

Your Learning Outcomes

You will be able to:

1. Draw and interpret Lewis structures for atoms.
2. Make predictions about molecular structure and composition based on the Lewis structures of atoms.

The Plan

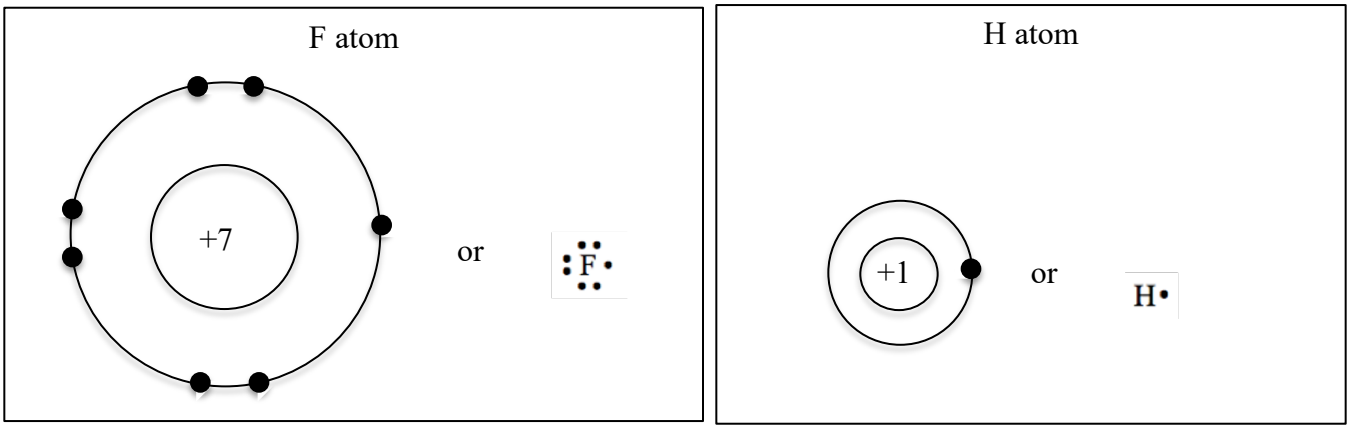
1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

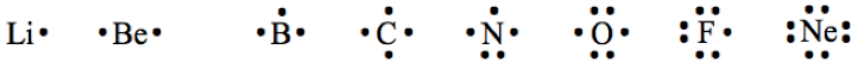
Model 1: Common Methods to Designate Atoms.

We have seen that a hydrogen atom has a core charge of +1 and that a neutral hydrogen atom has one valence electron. Also, we have seen that a fluorine atom has a core charge of +7 and seven valence electrons. Thus, we have represented these two atoms as shown in Figure 1 below. Alternatively, we could represent each atom with the appropriate atomic symbol and a dot or each valence electron, also shown in Figure 1. The latter designation takes up less space, makes the atom easily identifiable, and are more concise; the core charge is not explicit, however, and it is the responsibility of the reader to keep the core charge in mind.

Figure 1. Two methods to designate atoms.



G. N. Lewis proposed the following as representations of the valence electrons for the groups indicated.

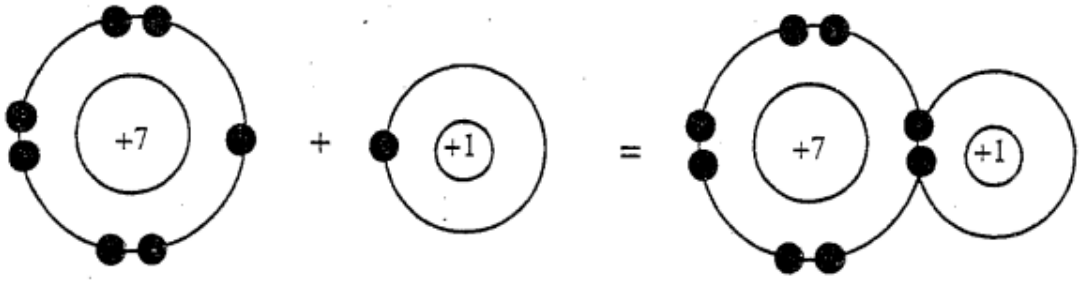


Critical Thinking Questions

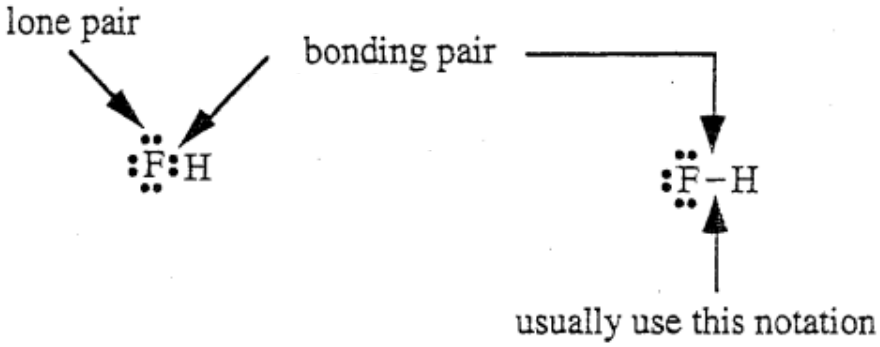
1. For each of the following neutral atoms, give the core charge.
   a. Li +1
   b. Cl +7
   c. He +2
2. Give the Lewis structure representation for each of the following atoms.
   a. Iodine I
   b. Calcium Ca
   c. Phosphorus P

Model 2: Lewis Structures of Molecules

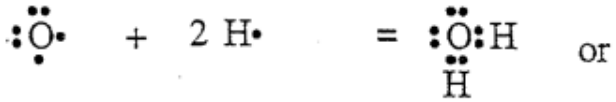
The delocalization of two electrons to form a bond results in the sharing of the two electrons in

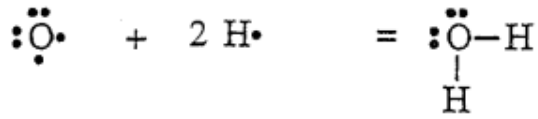


Or, more simply,



Another example,





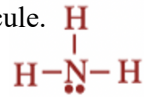
the valence shell of both atoms.

Information

Here are two rules for Lewis structures:

- Hydrogen must share two electrons—a bonding pair.
- The sum of the shared (bonding) electrons and the lone pair electrons for carbon, nitrogen, oxygen, and fluorine atoms must be eight—an **octet**. Usually, the other elements in groups 14, 15, 16, 17, also follow the octet tule.

3. Given the shell model of the atom, suggest a possible reason that Lewis proposed a maximum of two electrons for hydrogen and a maximum of eight for carbon, nitrogen, oxygen, and fluorine atoms?
   Because hydrogen can only have two electrons in its valence shell (n=1); carbon, nitrogen, oxygen, and fluorine can have eight electrons in its valence shell (n=2).

4. Answer the following for the nitrogen atom:
   a. What is the Lewis structure for N? 
   b. How many additional electrons does one N atom require when it forms a molecule?
      three
   c. What is the likely formula for a molecule composed of hydrogen atoms and one nitrogen atom? Draw the Lewis structure for this molecule.
      NH_3 

5. What is the likely formula for a molecule composed of hydrogen atoms ad one sulfur atom? Draw the Lewis structure for this molecule.
   SH_2 

6. Make a checklist that can be used to determine if a Lewis structure for a molecule is correct.
   1. Does the total number of electrons in the Lewis structure equal the total number of valence electrons in the molecules?
   2. Are there two electrons "around" each hydrogen atom?
   3. Are there eight electrons "around" all other atoms?
   4.
7. Without attempting to draw a Lewis structure, calculate the total number of valence electrons in each of these molecules:
   a. H_2CO
      12
   b. N_2
      10
   c. Cl_2
      14

Model 3: Lewis Structures of Some Molecules.

H_2CO N_2 Cl_2

8. What is the total number of electrons in the Lewis structures in Model 3 for each molecule:
   a. H_2CO
      12
   b. N_2
      10
   c. Cl_2
      14
9. Compare your answers to Questions 7 and 8. How does one determine the total number of electrons that should be used to generate a Lewis structure?
   The total number of electrons used to generate the Lewis structure equals the total number of valence electrons in the molecule.

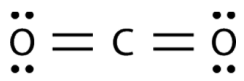
10.
   a. For Cl_2, what is the sum of the bonding electrons and lone pair electrons (also known as nonbonding electrons) around each Cl atom?
      8 (you count the two bonding electrons "around" each of the Cl atoms).
   b. For N_2, what is the sum of the bonding and nonbonding electrons around each N atom?
      8

11. For H_2CO:
   a. What is the sum of the bonding electrons and lone pair electrons around the C atom?
      8
   b. What is the sum of the bonding and nonbonding electrons around the O atom?
      8 (you count all six of the bonding electrons as being "around" each of the N atoms).

12. For Questions 10 and 11, confirm that the number of electrons around each atom is consistent with the Lewis model.
   Yes, there are eight electrons around all of these atoms.

13. Revise (as necessary) your checklist from Question 6 that can be used to determine if a Lewis structure for a molecule is correct.
   1. Does the total number of electrons in the Lewis structure equal the total number of valence electrons in the molecules?
   2. Are there two electrons "around" each hydrogen atom? Note: each bonding electron is counted as being "around" each of the bonding atoms.
   3. Are there eight electrons "around" all other atoms?

14. Use your checklist to determine whether or not the following is a correct Lewis structure for CO_2:



   Yes, it is correct. There should be 6 x 2 + 4 = 16 electrons in the Lewis structure (and there are). There are eight electrons around all atoms.