

Recitation  
Week 6  
Lewis Structures I

(What makes a molecule?) **KEY**

**Information**

We have talked about core electrons being those in an atom's completed set of shells. On the other hand the valence electrons are the outermost and most reactive electrons of an atom, those that determine how the atom bonds in a given molecule.

FACT: The properties of a molecule depend on how the electrons are distributed in the molecule.

For example

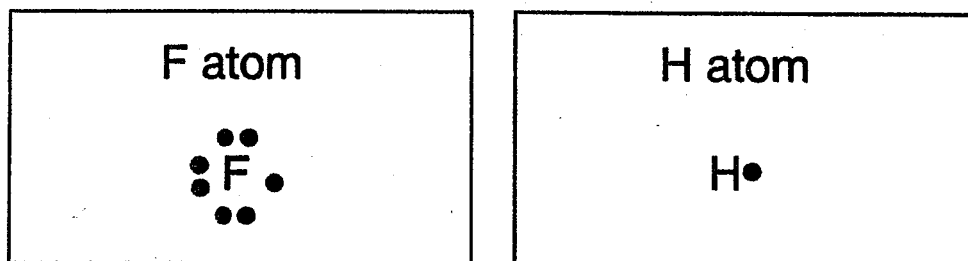
- a) it takes more energy to separate an oxygen atom from a carbon atom in a molecule of carbon monoxide, CO, than it does to separate an oxygen atom from a carbon atom in a molecule of Carbon dioxide, CO<sub>2</sub>.
- b) CO<sub>2</sub> is a linear molecule (the three nuclei in a straight line), whereas H<sub>2</sub>O is not linear (the three nuclei do not lie in a straight line).

These experimentally determined examples can be predicted by making diagrams 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.

**Model 1: Lewis Designation of Atoms**

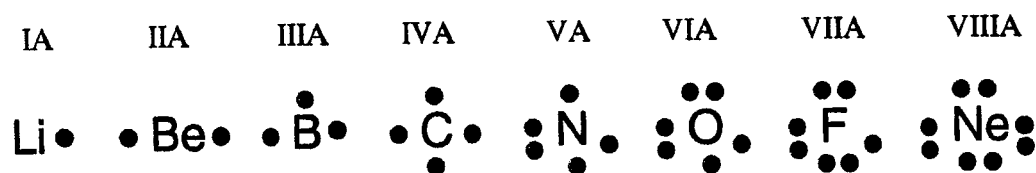
Figure 1. The Lewis designation.





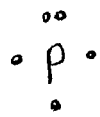
We have represented atoms of Fluorine and Hydrogen in figure 1. We represent these atoms as the chemical symbol for that element, surrounded by the appropriate number of dots, one dot for each *valence electron*. This approach makes the number of valence electrons easily identifiable.

G.N. Lewis proposed the following (Figure 2) as representations of the valence electrons for the groups indicated. We use the 2<sup>nd</sup> period elements in this example.

Figure 2. Lewis structures of atoms in period 2.

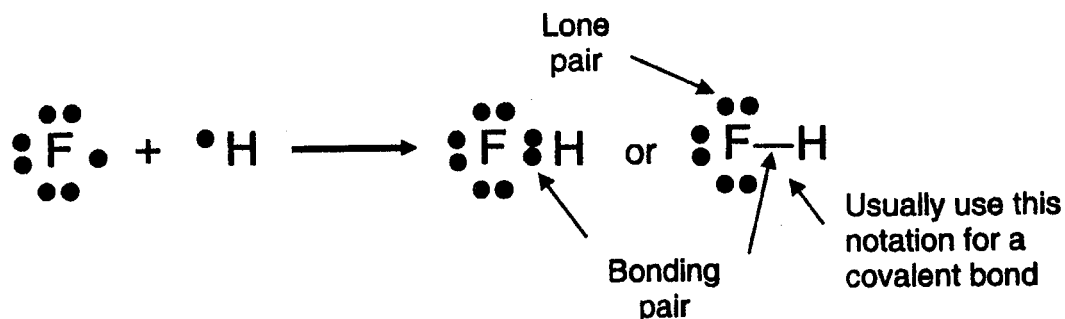


### Critical Thinking Questions

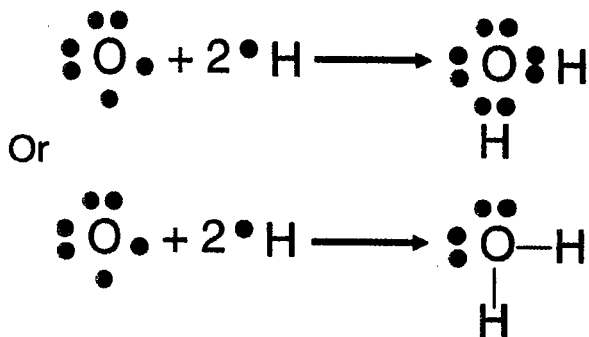
- What connection can you make with the number of valence electrons shown in figure 2 and the group number of the element represented?  
*The number of valence electrons is the same as the (main) group number.*
- What do you think valence electrons are? What are core electrons?  
*Valence electrons are the outermost and most reactive electrons. Core electrons are those associated with full inner shells.*
- Why do we consider valence electrons differently to core electrons?  
*The valence electrons are those that determine the reactivity of the element.*
- Give the Lewis representation for each of the following atoms.
  - Iodine 
  - Calcium 
  - Phosphorus 

### Model 2: Lewis Structures for Molecules

The Covalent Bond – the sharing of two electrons in the valence shell of both atoms:



Another example



### 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 main groups IV, V, VI and VII also follow the octet rule.

### Critical Thinking Questions

5. Given the shell model of the atom, why do you think Lewis proposed a maximum of two electrons for hydrogen and a maximum of eight for carbon, nitrogen, oxygen, and fluorine atoms?

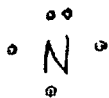
Hydrogen only needs one more electron to fill the 1st shell.  
Carbon, nitrogen, oxygen and fluorine atoms all are closer to

6. How many valence electrons does N have?

5

filling the 2nd shell which accommodates 8 electrons

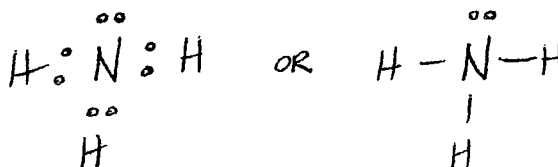
- a. What is the Lewis representation for N?



- b. How many additional electrons does one N atom require when it forms a molecule?

3

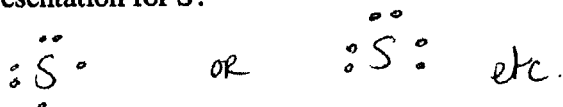
- c. What is the likely formula for a molecule composed of hydrogen atoms and one nitrogen atom? Draw the Lewis structure for this molecule.



7. Answer the following for the sulfur atom:  
 a. How many valence electrons does S have?

6

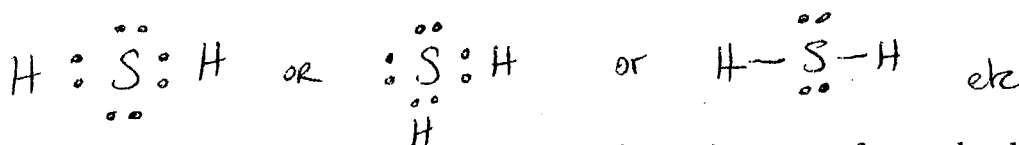
- b. What is the Lewis representation for S?



- c. How many additional electrons does one S atom require when it forms a molecule?

2.

- d. What is the likely formula for a molecule composed of hydrogen atoms and one sulfur atom? Draw the Lewis structure for this molecule.



8. Make a checklist that can be used to determine if a Lewis structure for a molecule is correct.

H must be sharing 2 electrons  
 Other atoms typically must have access to eight electrons  
 (either from a bond or from lone pairs)  
 All the valence electrons for each atom are to be accounted for  
 H can only bind to one atom at a time.

9. Without attempting to draw a Lewis structure, calculate the total number of valence electrons in each of these molecules:

- a.  $H_2CO$

$$2 \times 1 + 1 \times 4 + 1 \times 6 \quad (H, C, O) = 12$$

- b.  $N_2$

$$2 \times 5 = 10$$

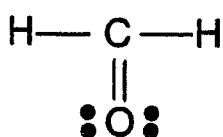
- c.  $Cl_2$

$$2 \times 7 = 14$$

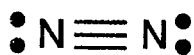
- d.  $OH^-$

$$6 + 1 + 1 = 8 \quad (\text{Oxygen} + \text{Hydrogen} + \text{one electron}) \\ (\text{charge on ion})$$

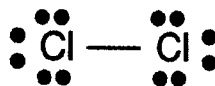
Model 3: Lewis Structures of some molecules



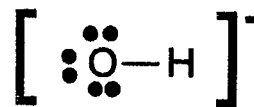
H<sub>2</sub>CO



N<sub>2</sub>



Cl<sub>2</sub>



OH<sup>-</sup>

Critical Thinking Questions

10. What is the total number of electrons in the Lewis structure in Model 3 for each of:

a. H<sub>2</sub>CO

12

b. N<sub>2</sub>

10

c. Cl<sub>2</sub>

14

d. OH<sup>-</sup>

8

11. Compare your answers to CTQs 9 and 10. How does one determine the total number of electrons that should be used to generate a Lewis structure?

You must use all the valence electrons in the Lewis structure.

12. For Cl<sub>2</sub>, is the sum of the bonding electrons and the lone pair electrons (also called nonbonding electrons) around each chlorine consistent with the Lewis model?

Yes.

13. For N<sub>2</sub>, is the sum of the bonding electrons and the lone pair electrons around each Nitrogen consistent with the Lewis model?

Yes

14. For  $\text{H}_2\text{CO}$ :

a. Is the sum of the bonding electrons and lone pair electrons around the carbon atom consistent with the Lewis model? *Yes*

b. Is the sum of the bonding electrons and lone pair electrons around the oxygen atom consistent with the Lewis model? *Yes.*

15.

a. For  $\text{OH}^-$ , what can you say about the number of electrons included in this structure?

*The number of electrons is made up of the valence electrons for each atom along with an electron contributed by the negative charge*

b. Is the sum of the bonding electrons and lone pair electrons around the oxygen atom consistent with the Lewis model?

*Yes, and more specifically the octet is completed,*

c. Is the sum of the bonding electrons and lone pair electrons around the hydrogen atom consistent with the Lewis model?

*Yes.*

d. Give an expression for the link between the charge on a polyatomic ion and the total number of valence electrons for that polyatomic ion? (How do you think the charge on that ion affects the total number of electrons?)

*The total number of electrons in the Lewis structure must be the sum of the valence electrons from each atom and the number of extra electrons associated with the negative charge on the ion. A positive charge denotes that one electron has been lost and so we must adjust accordingly.*

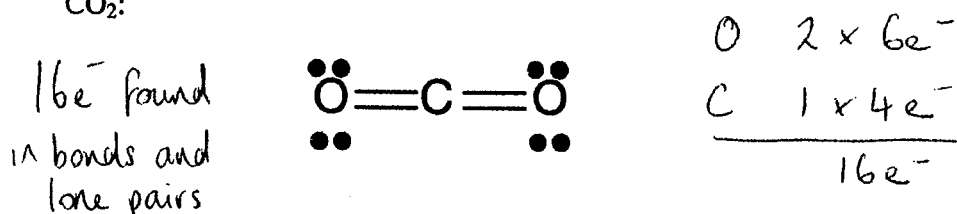
16. Revise (as necessary) your checklist that can be used to determine if a Lewis structure for a molecule is correct.

*Make sure a statement associated with the sum of the valence electrons is included in your checklist.*

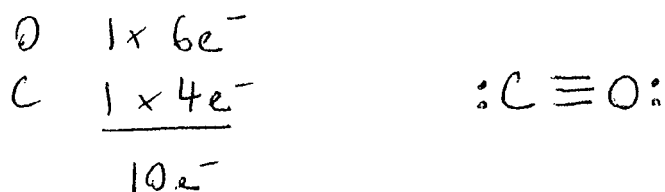
*The charge on the polyatomic ion must be accounted for*

Charge	+ 2	+ 1	0	- 1	- 2	- 3
Change in total number of electrons	- 2e <sup>-</sup>	- 1e <sup>-</sup>	0	+ 1e <sup>-</sup>	+ 2e <sup>-</sup>	+ 3e <sup>-</sup>

17. Use your checklist to determine whether or not the following is a correct structure for  $\text{CO}_2$ :



18. Write down the correct Lewis structure for carbon monoxide,  $\text{CO}$ .



See rules for building Lewis Structures.

19. Why do you think it takes more energy to break a carbon oxygen bond in carbon monoxide than in carbon dioxide.

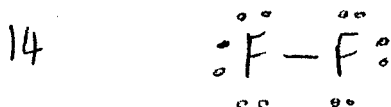
The carbon-oxygen bond in  $\text{CO}$  is a triple bond and is likely stronger than each carbon-oxygen double bond in  $\text{CO}_2$ .

### The OCTET RULE

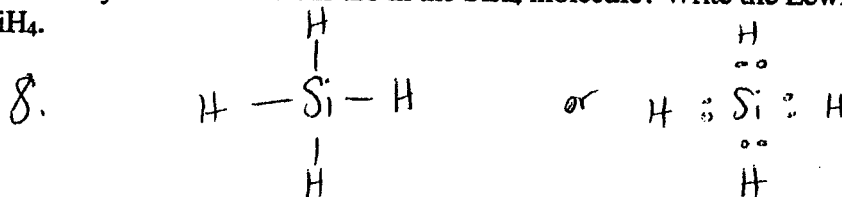
In their compounds, the sum of the shared (bonding) electrons and the lone pair electrons for carbon, nitrogen, oxygen, and fluorine atoms must be eight – an octet. Usually the other elements in main groups IV, V, VI and VII also follow the octet rule.

20. Is the octet rule obeyed in all of the Lewis structures of CTQ's 12, 13, 14, 15, 17 and 18?  
 It's obeyed for those 2nd period elements, yes.

21. How many valence electrons are in the  $\text{F}_2$  molecule? Write the Lewis structure for  $\text{F}_2$ .



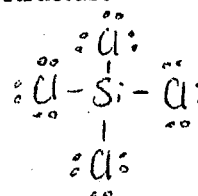
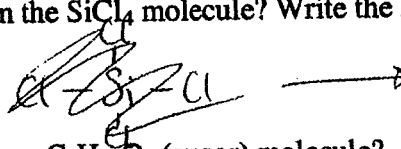
22. How many valence electrons are in the  $\text{SiH}_4$  molecule? Write the Lewis structure for  $\text{SiH}_4$ .



**Exercises –**

23. How many valence electrons are in the  $\text{SiCl}_4$  molecule? Write the Lewis structure for  $\text{SiCl}_4$ .

32



24. How many valence electrons are in a  $\text{C}_6\text{H}_{12}\text{O}_6$  (sugar) molecule?

$$6 \times 4 + 12 \times 1 + 6 \times 6 = 72$$

25. How many valence electrons are in the  $\text{NH}_4^+$  ion?

$$5 + 4 \times 1 - 1(\text{Charge}) = 8$$

26. How many valence electrons are in the  $\text{CN}^-$  ion?

$$4 + 5 + 1 = 10$$

(Charge)