Molecular Compounds

bromine gas
(element containing covalent bonds)
Br_2

Water
H_2O

Sucrose
$C_{12}H_{22}O_{11}$

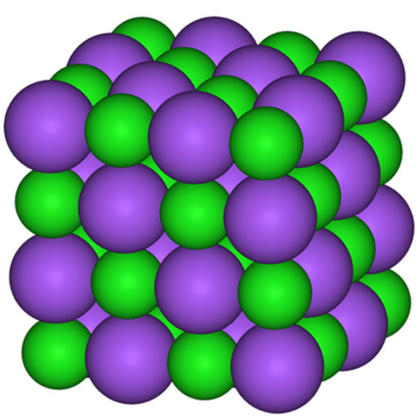
Polytheylene
(polymer – repeating subunits)
$(C_2H_4)_n$

acetylsalicylic acid (aspirin)
$C_9H_8O_4$

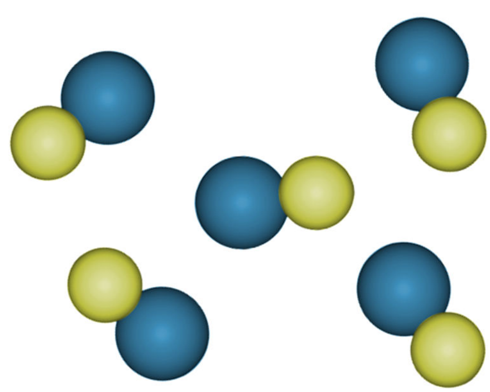
Dinitrogen monoxide
(nitrous oxide / laughing gas)
$C_{19}H_{19}N_7O_6$

A molecule is a combination of atoms linked together by ________________ bonds. Once bonded, each molecule acts as one unit. Individual molecules interact with each other and with other substances. Since electrons are shared between atoms to achieve a stable octet, the strength of the interactions **within** a molecular compound are highly variable depending on which elements are involved. The interactions **between** molecules are also highly variable depending on the polarity and three dimensional shape of molecules. As a result, molecular compounds have an astonishing, and seemingly limitless variety of physical and chemical properties.

Concept of an Ionic Compound

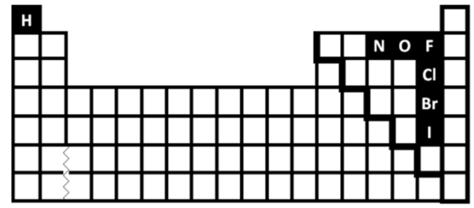


Concept of a Molecular Compound



Molecular Elements?

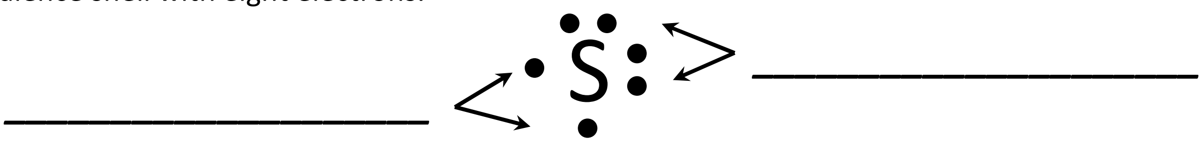
Some molecules consist of only one type of element. When two atoms of the same element are able to bond to each other they are known as __________________ elements. More than two of the same element can combine for some elements. For example three oxygen atoms can combine to form ozone (O_3).



The diatomic elements

Bonding Capacity

Typically, each element will only form a certain number of bonds (ionic or covalent) in order to achieve a stable octet. For example, sulfur has six valence electrons, therefore it will typically form two bonds to fill its valence shell with eight electrons.



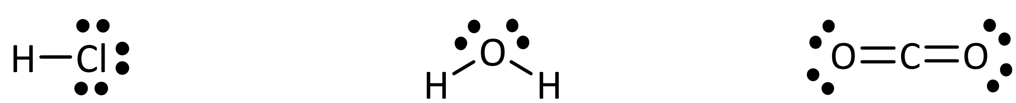
The unpaired electrons in the valence shell are the electrons involved in chemical bonds, therefore they are referred to as ______________________________. The number of bonding electrons corresponds with the number of bonds that can be formed, also known as the _____________________. The paired electrons that are not involved in chemical reactions are called ________________________.

Complete the table below

element	hydrogen	carbon	nitrogen	oxygen	fluorine
Lewis diagram					
bonding electrons					
bonding capacity					
lone pairs					

Lewis Structures

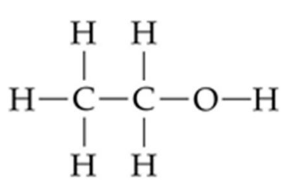
Chemists often draw two dimensional representations of molecules using Lewis diagrams. A single dash in a Lewis **structure** represents a single covalent bond. Lone pairs are shown and are important for determining 3D shape.



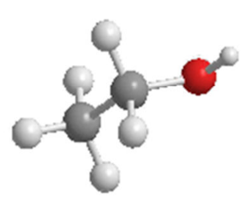
Other Ways to Represent Molecules

Ethyl alcohol
Name

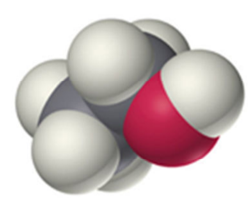
C_2H_6O
Chemical formula



Structural formula



Ball and stick model



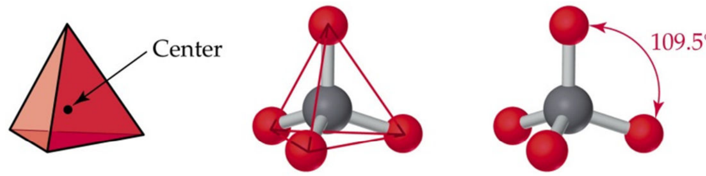
3D model

Molecular Shapes

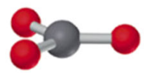
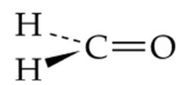
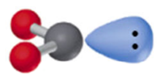
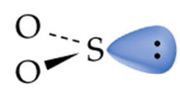
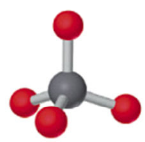
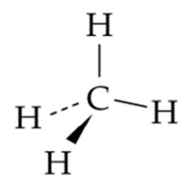
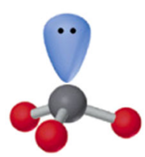
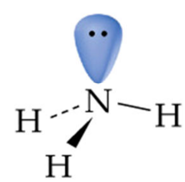
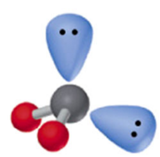
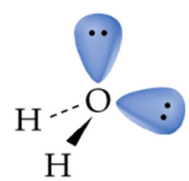
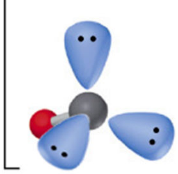
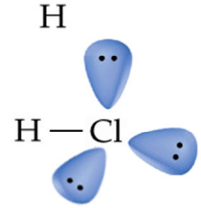
According to the Valence Shell Electron Pair Repulsion (VSEPR) theory, electron pairs and hence bonded atoms will maximally space themselves from each other.

bonding pair

lone pair



A regular tetrahedron **(a)** | **(b)** | A tetrahedral molecule **(c)**

Number of Bonds	Number of Lone Pairs	Number of Charge Clouds	Molecular Geometry	Example
2	0	2	 Linear	O=C=O
3	0	3	 Trigonal planar	
2	1	3	 Bent	
4	0	4	 Tetrahedral	
3	1	4	 Trigonal pyramidal	
2	2	4	 Bent	
1	3	4	 Linear	

Determining Complex Lewis Structures:

The Has / Need Method

This method will help you solve the Lewis structure for any molecular compound. Many Lewis structures are intuitive with practice, however, this method is particularly useful for more complex compounds.

Step 1 – Create a table with each element present in the compound listed vertically along the left side. If the compound has a charge (i.e. it is an ion), include the symbol $\mathbf{e}^-$ to account for the extra or fewer electrons.

Step 2 – Label the second column **"Has"** and list the number of valence electrons present in each element. Multiply by the number of each atom present in the compound. For ions, include a tally of excess electrons based on the ionic charge. List negative values for electrons for positive ions.

Step 3 – Label the third column **"Needs"** and list the number of valence electrons needed for each element to become stable (i.e. isometric with the nearest Nobel gas). Multiply by the number of each atom present in the compound.

Step 4 – Total each column.

Step 5 – Find the difference between the number of electrons present and needed. Divide this number by 2 to determine the number of bonds that will form.

Step 6 – Determine the central atom where applicable (this is often the element with the highest bonding capacity). Arrange the other elements around the central atom and begin linking them with dashes to represent single bonds until all available bonds have been placed. If there are insufficient bonds to satisfy the bonding capacity of each element, use double or triple bonds as needed.

Step 7 – All electrons present (i.e. the "Has" column total) must be placed. Counting each bond as two electrons, place the remaining electrons as lone pairs around each atom to satisfy the octet rule. Remember, hydrogen will not hold lone pairs.

** Note: Some elements can be stable with an "expanded" or "reduced" octet.*
Boron and Aluminum can be stable with 6 valence electrons.
Phosphorus can be stable with 10 valence electrons (5 bonds)
Sulfur can be stable with 12 valence electrons (6 bonds)

Example: Solve the Lewis structure of the nitrate ion (NO_3^-)