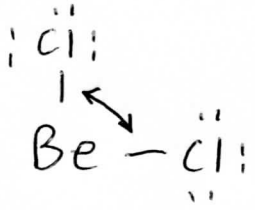
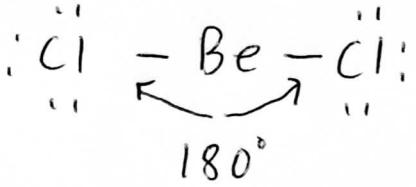
Chemistry Lecture #41: Shapes of Molecules

We can predict the arrangement of terminal atoms attached to the central atom of a molecule using valence shell electron pair repulsion theory (VSEPR theory). This states that pairs of valence electrons on the central atom will be arranged in space to put the greatest distance between the electrons. As a result, molecules will take distinctive shapes.

Beryllium normally forms ionic bonds with nonmetals, but it will form covalent bonds with group 7 elements. Below is a Lewis diagram of $BeCl_2$.

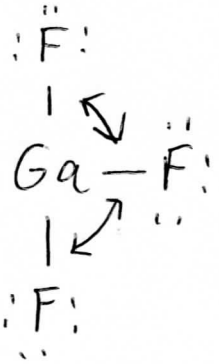


Be forms two bonds, each of them with Cl. Each bond has a pair of electrons. The shape that puts the greatest distance between the bonds is a straight line or linear shape.

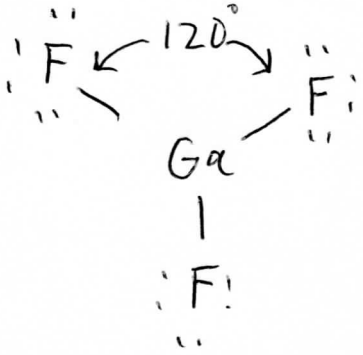


Thus, a molecule will have linear shape if two terminal atoms are attached to the central atom. The bond angle is 180 degrees.

Aluminum and Gallium will form covalent bonds with group 7 elements. Below is a Lewis diagram of GaF_3.

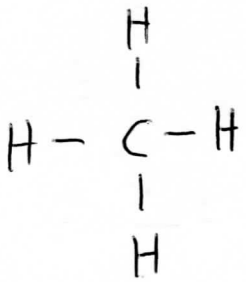


The shape that puts the greatest distance between the bonds is a triangle shape. The triangle that is formed is a flat triangle that sits on a single plane. The shape is called trigonal planar, and the angle between the bonds is 120 degrees.



Thus, a molecule will have a trigonal planar shape if three terminal atoms are attached to the central atom.

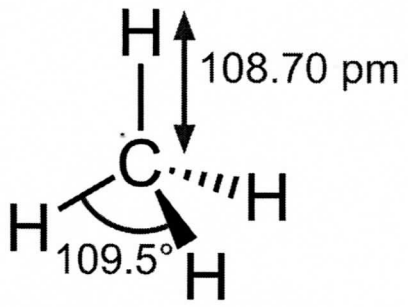
Below is a Lewis structure for CH_4.



There are 4 bonds in this molecule. The diagram shows a flat molecule, and the bonds appear to be at right angles to each other. Is this the shape that puts the greatest distance between the bonds? Yes, it is - *in two dimensions!*

We live in a three dimensional world. The bonds can point up & down, left & right in two dimensions. In three dimensions it can also point forward & back. The bonds can be spaced further apart if we take advantage of the forward and backward directions.

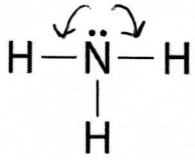
Below is a picture of the three dimensional shape of CH_4.



The long, triangle shaped bond is coming toward you. The bond consisting of dashes is pointing away from you. The bond length is 108.70 picometers.

The bond angle is 109.5 degrees, which is more than the 90 degrees you'd get with a flat, two dimensional shape. The name of this shape is tetrahedral. A molecule will have a tetrahedral shape if four terminal atoms are attached to the central atom.

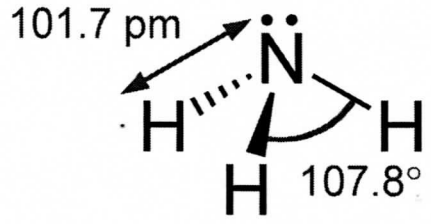
Below is a Lewis diagram of NH_3.



Ammonia

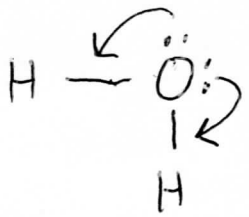
What will be the shape of this molecule? It has 3 terminal atoms attached to the central atom, so you might think that it will have a trigonal planar shape. But NH_3 also has a pair of unshared electrons on the nitrogen. These electrons push down on the other bonds, giving it a shape like a pyramid.

Below is the shape of NH_3.



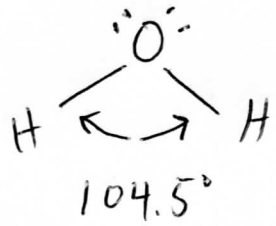
The bond length is 101.7 pm, & the bond angle is 107.8 degrees. Since the base of the shape is a triangle, and since the overall shape is that of a pyramid, the name of the shape is trigonal pyramidal. Molecules will take this shape if there is a pair of unshared electrons on the central atom, and three terminal atoms are attached to the central atom..

Below is a Lewis diagram of H_2O.



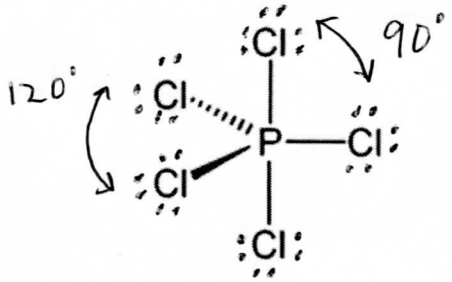
The two sets of unpaired electrons on the oxygen will push down on the bonds, preventing the molecule from having a linear shape.

Below is the shape of H_2O.



The bond angle is 104.5 degrees. The name of the shape is bent. A molecule will have a bent shape when the central atom has one or more pairs of unshared electrons, and two terminal atoms are attached to the central atom.

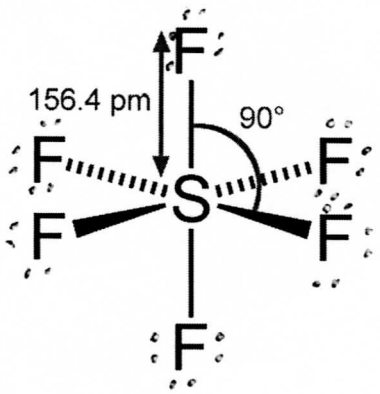
PCl_5 is a molecule where phosphorous has an expanded octet. The shape is shown below.



This shape shows phosphorous surrounded by three chlorine atoms in the same plane, with two additional chlorine atoms above and below the phosphorous.

When five terminal atoms are attached to the central atom, the shape is trigonal bipyramidal. The bond angle between some adjacent chlorine atoms are 120 degrees. Other angles are 90 degrees.

SF_6 also has an atom with an expanded octet. The structure is shown below.



The bond length between S and F is 156.4 pm. Adjacent bond angles between S and F are 90 degrees.

When six terminal atoms are attached to the central atom, the name of the shape is octahedral.

There are many other shapes, but this is all we need to know for the high school level.