19.7: Molecular Shapes- No Lone Pairs on Central Atoms

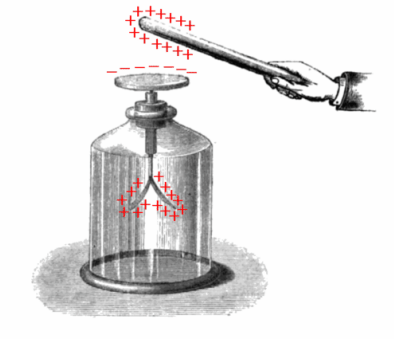


Figure 19.7.1(Public Domain; Sylvanus P. Thompson via Wikipedia)

How does an electroscope work?

An electroscope is a device used to study charge. When a positively charged object (the rod) nears the upper post, electrons flow to the top of the jar, leaving the two gold leaves positively charged. The leaves repel each other since both hold positive, like charges. The VSEPR theory says that electron pairs, also a set of like charges, will repel each other such that the shape of the molecule will adjust, so that the valence electron pairs stay as far apart from each other as possible.

Central Atom with No Lone Pairs

In order to easily understand the types of molecules possible, we will use a simple system to identify the parts of any molecule:

- A = **central atom** in a molecule
- B = atoms surrounding the central atom

Subscripts after the B will denote the number of B atoms that are bonded to the central A atom. For example, AB_4 is a molecule with a central atom surrounded by four covalently bonded atoms. Again, it does not matter if those bonds are single, double, or triple bonds.

AB_2: Beryllium Hydride (BeH_2)

Beryllium hydride consists of a central beryllium atom with two single bonds to hydrogen atoms. Recall that it violates the octet rule.

$$H-Be-H$$

According to the requirement that electron pairs maximize their distance from one another, the two bonding pairs in the BeH_2 molecules will arrange themselves on directly opposite sides of the central Be atom. The resulting geometry is a linear molecule, shown in the figure below in a "ball and stick" model.

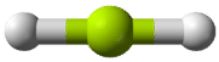


Figure 19.7.2 Beryllium hydride model. (Public Domain; Ben Mills (User:Benjah-bmm27/Wikimedia Commons) via Wikipedia)

The bond angle from $H-Be-H$ is 180^o because of its linear geometry.

Carbon dioxide is another example of a molecule which falls under the AB_2 category. Its Lewis structure consists of double bonds between the central carbon and the oxygen atoms (see figure below).

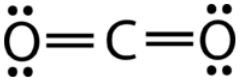


Figure 19.7.3 Carbon dioxide bonding. (CC BY-NC 3.0; Joy Sheng via CK-12 Foundation)

The repulsion between the two groups of four electrons (two pairs) is no different than the repulsion of the two groups of two electrons (one pair) in the BeH_2 molecule. Carbon dioxide is also linear (see figure below).

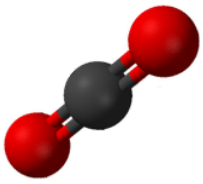


Figure 19.7.4 Carbon dioxide. (Public Domain; User:Benji9072/Wikimedia Commons via Wikipedia)

AB_3: Boron Trifluoride (BF_3)

Boron trifluoride consists of a central boron atom with three single bonds to fluorine atoms (see figure below). The boron atom also has an incomplete octet.

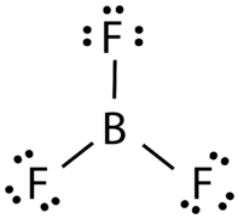


Figure 19.7.5 Boron trifluoride bonding. (CC BY-NC 3.0; Joy Sheng via CK-12 Foundation)

The geometry of the BF_3 molecule is called trigonal planar (figure 19.7.3). The fluorine atoms are positioned at the vertices of an equilateral triangle. The $F-B-F$ angle is 120^o and all four atoms lie in the same plane.

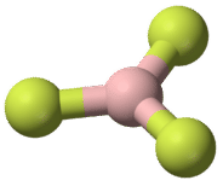


Figure 19.7.6 Boron trifluoride model. (Public Domain; User:Benji9072/Wikimedia Commons via Wikipedia)

AB_4: Methane (CH_4)

Methane is an organic compound that is the primary component of natural gas. Its structure consists of a central carbon atom with four single bonds to hydrogen atoms (see figure below). In order to maximize their distance from one another, the four groups of bonding electrons do not lie in the same plane. Instead, each of the hydrogen atoms lie at the corners of a geometrical shape called a tetrahedron. The carbon atom is at the center of the tetrahedron. Each face of a tetrahedron is an equilateral triangle.

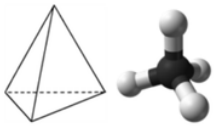


Figure 19.7.7 Tetrahedral structure of methane. (Public Domain; (Left) Pearson Scott Foresman; (Right) Ben Mills (Wikimedia: Benjah-bmm27) via (Left) http://commons.wikimedia.org/wiki/File:Tetrahedron_(PSF).png; (Right) http://commons.wikimedia.org/wiki/File:Methane-CRC-MW-3D-balls.png)

The molecular geometry of the methane molecule is tetrahedral (see figure 19.7.5). The $H-C-H$ bond angles are 109.5^o, which is larger than the 90^o that they would be if the molecule was planar. When drawing a structural formula for a molecule such as methane, it is advantageous to be able to indicate the three-dimensional character of its shape. The structural formula below is called a perspective drawing. The dotted line bond is to be visualized as receding into the page, while the solid triangle bond is to be visualized as coming out of the page.

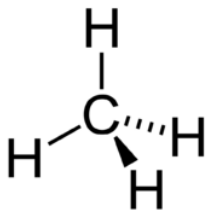
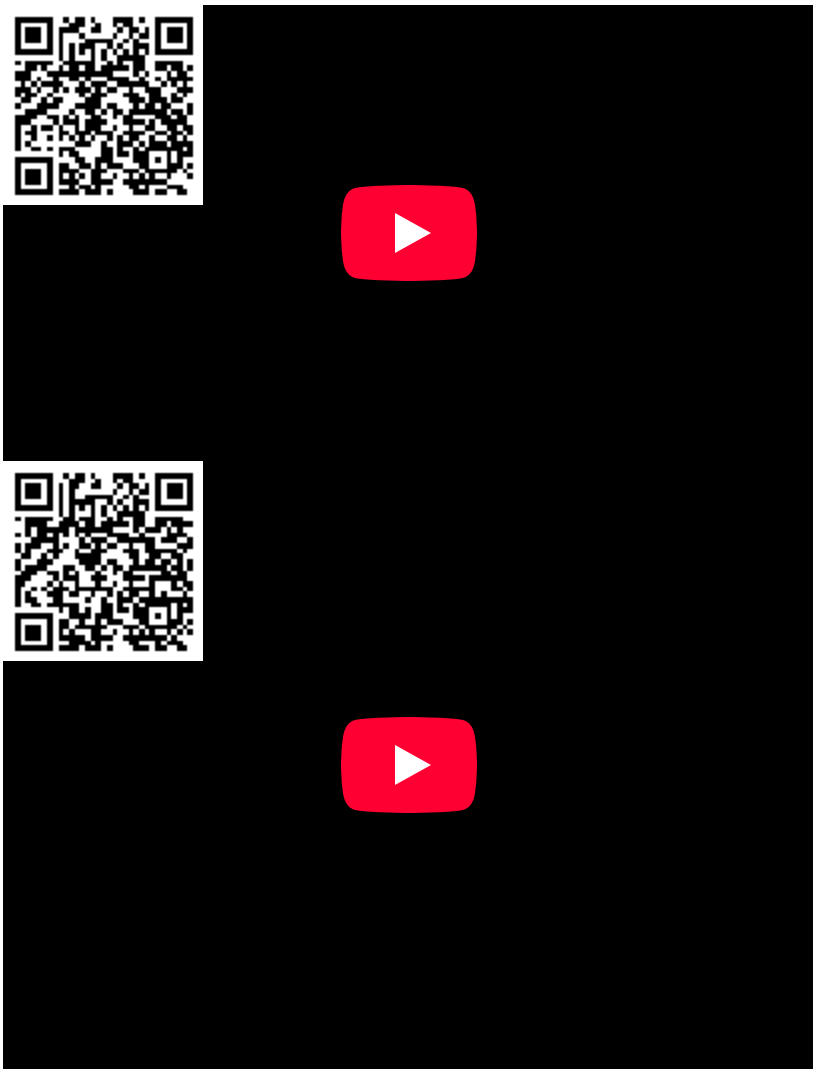


Figure 19.7.8 Methane perspective model. (CC BY-NC 3.0; Joy Sheng via CK-12 Foundation)



Summary

- Electron pairs repel each other and influence bond angles and molecular shape.

Review

1. What are the bond angles in carbon dioxide?
2. What molecule has bond angles of 109.5°?
3. What is the geometry of the BF_3 molecule?
