

STUDY GUIDE *AP Chemistry*

CHAPTER NINE- MOLECULAR GEOMETRY AND BONDING THEORIES

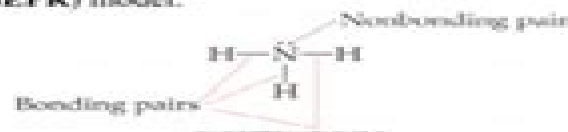
SECTIONS 9.1 THROUGH 9.6 ONLY

9.1 Molecular Shapes

- Lewis structures give atomic connectivity; they tell us which atoms are physically connected to which atoms.
- The shape of a molecule is determined by its **bond angles**.
 - The angles made by the lines joining the nuclei of the atoms in a molecule are the bond angles.
- Consider CCl_4 :
 - Experimentally we find all $\text{Cl}-\text{C}-\text{Cl}$ bond angles are 109.5° .
 - Therefore, the molecule cannot be planar.
 - All Cl atoms are located at the vertices of a tetrahedron with the C at its center.
- In order to predict molecular shape, we assume that the valence electrons repel each other.
 - Therefore, the molecule adopts the three-dimensional geometry that minimizes this repulsion.
 - We call this model the **Valence Shell Electron Pair Repulsion (VSEPR)** model.

9.2 The VSEPR Model

- A covalent bond forms between two atoms when a pair of electrons occupies the space between the atoms.
 - This is a **bonding pair** of electrons.
 - Such a region is an **electron domain**.
- A **nonbonding pair** or *lone pair* of electrons defines an electron domain located principally on one atom.
- Example: NH_3 has three bonding pairs and one lone pair.
- VSEPR predicts that the best arrangement of electron domains is the one that minimizes the repulsions among them.
 - The arrangement of electron domains about the central atom of a molecule is its **electron-domain geometry**.
 - There are five different electron-domain geometries:
 - linear (two electron domains), trigonal planar (three domains), tetrahedral (four domains), trigonal bipyramidal (five domains) and octahedral (six domains).
- The **molecular geometry** is the arrangement of the atoms in space.
 - To determine the shape of a molecule we must distinguish between lone pairs and bonding pairs.
 - We use the electron-domain geometry to help us predict the molecular geometry.
 - Draw the Lewis structure.
 - Count the total number of electron domains around the central atom.
 - Arrange the electron domains in one of the five geometries to minimize electron-electron repulsion.
 - Next, determine the 3-D structure of the molecule.
 - We ignore lone pairs in the molecular geometry.
 - Describe the molecular geometry in terms of the the bonded atoms.
 - Multiple bonds are counted as one electron domain.



Number of Electron Domains	Arrangement of Electron Domains	Electron-Domain Geometry	Predicted Bond Angles
2		Linear	180°
3		Trigonal planar	120°
4		Tetrahedral	109.5°
5		Trigonal bipyramidal	120° 90°
6		Octahedral	90°

The Effect of Nonbonding Electrons and Multiple Bonds on Bond Angles

We refine VSEPR to predict and explain slight distortions from "ideal" geometries.

- Consider three molecules with tetrahedral electron domain geometries: CH_4 , NH_3 , and H_2O .
 - By experiment, the $\text{H}-\text{X}-\text{H}$ bond angle decreases from C (109.5° in CH_4) to N (107° in NH_3) to O (104.5° in H_2O).
 - A bonding pair of electrons is attracted by two nuclei. They do not repel as much as lone pairs which are primarily attracted by only one nucleus.
 - Electron domains for nonbonding electron pairs thus exert greater repulsive forces on adjacent electron domains.
 - They tend to compress the bond angles.
 - The bond angle decreases as the number of nonbonding pairs increases.
 - Similarly, electrons in multiple bonds repel more than electrons in single bonds (e.g., in Cl_2CO the $\text{O}-\text{C}-\text{Cl}$ angle is 124.3° , and the $\text{Cl}-\text{C}-\text{Cl}$ bond angle is 111.4°).

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Margaret G. Kimble



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