# Molecular Geometry

Video Workbook with Dr. B.

*More guides at*
*www.breslyn.org*

*Lewis Structures* show the arrangement of atoms and electron pairs.

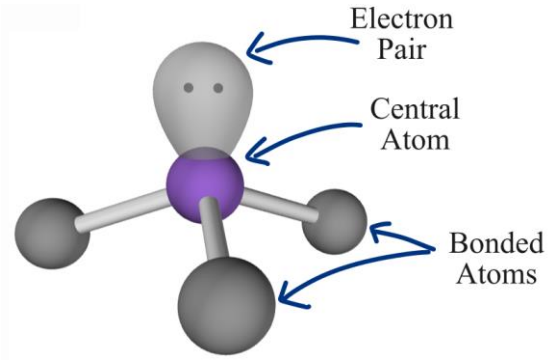
*Molecular Geometry* shows us the shape of molecules. VSEPR* tells us that the atoms and electron pairs around the central atom push each other away and spread out. This gives a molecule its shape/geometry.

*Valence Shell Electron Pair Repulsion Theory

Molecular Geometry

Molecular Geometry using AXN Notation

There are two main ways to find the Molecular Geometry for a molecule. Both look at the atoms and lone pairs bonded to the central atom.




Important Ideas

The **Electron Pair** (also called Lone Pair) has volume and occupies space, like atoms.

The Bonded Atoms and Electron Pairs have a negative charge on their surface and **repel** each other. But they stay bonded to the central atom.

They spread out to give the molecule its shape.

| Steric Number | Zero Lone Pairs | One Lone Pair | Two Lone Pairs |
|---|---|---|---|
| 2 | Linear, 180° | | |
| 3 | Trigonal Planar, 120° | Bent, 120° | |
| 4 | Tetrahedral, 109.5° | Trigonal Pyramidal, 109.5° | Bent, 109.5° |

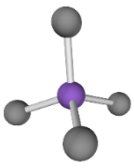
Steric Number is the number of domains (atoms and electron pairs) bonded to the central atom.

Note that the bond angles are general and can differ from the ideal values in the table.

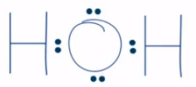
## Example: $CH_4$

Four atoms bonded to central atom.
Steric number is 4.
No lone pairs

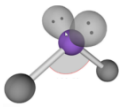
Geometry is Tetrahedral.
Bond angles are 109.5°



## Example: $H_2O$



Two atoms bonded to central atom.
Two lone pairs.
Steric number is 4.



Geometry is Bent
Bond angle is about 109.5° (actual 104.5°).

## Example: $NH_3$

Three atoms bonded to central atom.
One lone pair.
Steric number is 4.

Geometry is Trigonal Pyramidal.
Bond angle is about 109.5° (actual 107°).

Chart for higher steric numbers.

| Steric Number | Zero Lone Pairs | One Lone Pair | Two Lone Pairs |
|---|---|---|---|
| 5 | Trigonal bipyramidal | Seesaw | T-shaped |
| 6 | Octahedral | Square pyramidal | Square planer |

Steric Number is the number of domains (atoms and electron pairs) bonded to the central atom.

**Visualizing the Shapes of Molecules**

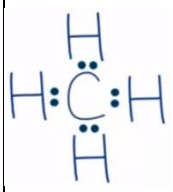
Visualizing how atoms and lone pairs repel each other will greatly enhance your understanding of VSEPR.

This free app is a powerful visualization tool:
https://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html

Practice

Use the app to build molecules of $CH_4$, $H_2O$, and $NH_3$ based on the Lewis Structures above.

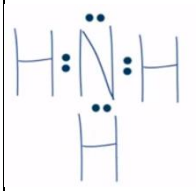
You can also use the **AXE notation**. A is the central atom, X is the number of bonding pairs (think of this as atoms), and E is the number of lone pairs bonded to the central atom.



For $CH_4$:

- C is the central atom so we write $A_1$ or just A.
- There are four atoms bonded to C so we write $X_4$.
- There are no lone pairs so we write $E_0$

We end up with $AX_4$ (we don't need to write $E_0$). Look $AX_4$ up, or memorize it, and we find that $AX_4$ is *tetrahedral*.

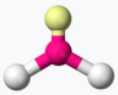
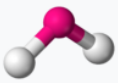
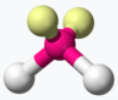
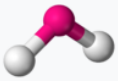
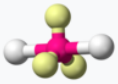
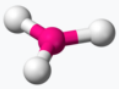
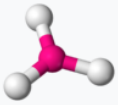


For $NH_3$:

- N is the central atom so we write $A_1$ or just A.
- There are three atoms bonded to N so we write $X_3$.
- There is one lone pair so we write $E_1$

We end up with $AX_3E_1$. Look that up, or memorize, we find that $AX_4E_1$ is *trigonal pyramidal*.

Charts like this are available on the web. [This is a portion of a AXE cart from Wikipedia](#).

| Molecule type | Shape[1]:413–414 | Electron arrangement[1]:413–414 including lone pairs, shown in pale yellow | Geometry[1]:413–414 excluding lone pairs | Examples |
|---|---|---|---|---|
| $AX_2E_0$ | Linear |  |  | $BeCl_2$,[3] $CO_2$[10] |
| $AX_2E_1$ | Bent |  |  | $NO_2^-$,[3] $SO_2$,[1]:413–414 $O_3$,[3] $CCl_2$ |
| $AX_2E_2$ | Bent |  |  | $H_2O$,[1]:413–414 $OF_2$[13]:448 |
| $AX_2E_3$ | Linear |  |  | $XeF_2$,[1]:413–414 $I_3^-$[13]:483 $XeCl_2$ |
| $AX_3E_0$ | Trigonal planar |  |  | $BF_3$,[1]:413–414 $CO_3^{2-}$[13]:368 $NO_3^-$,[3] $SO_3$[10] |

## Practice with Video Explanations

**Find the Molecular Geometry for the following molecules:**

| *Easy* | *Medium* | *Difficult* |
|---|---|---|
| $H_2$ https://youtu.be/qo9gLBZ-sn8 | $N_2$ https://youtu.be/H-6AFCQdGCo | $SF_6$ https://youtu.be/paGFbPChdPc |
| $CCl_4$ https://youtu.be/ykWLEu9f2Jg | $NO_2^-$ https://youtu.be/W84utFmGkac | $CH_3OH$ https://youtu.be/lMIibdPyNwI |
| HCN https://youtu.be/J01cT7eCAVg | $XeF_4$ https://youtu.be/N5T7NjgdC3I | $PCl_5$ https://youtu.be/hjdnbJIwz1g |
| $SO_2$ https://youtu.be/jyWmjiMa7hg | $ClO_2^-$ https://youtu.be/k9-rI2ztaZc | $BF_3$ https://youtu.be/f7VW2ZXBqlU |

### Answers

$H_2$ Linear
$CCl_4$ Tetrahedral
HCN Linear
$SO_2$ Bent

$N_2$ Linear
$NO_2^-$ Bent
$XeF_4$ Square Planar
$ClO_2^-$ Bent

$SF_6$ Octahedral
$CH_4OH$ Tetrahedral
$PCl5$ Trigonal Bipyramidal
$BF3$ Trigonal Planar

Report errors and suggestions to DrB@breslyn.org

*www.Breslyn.org*