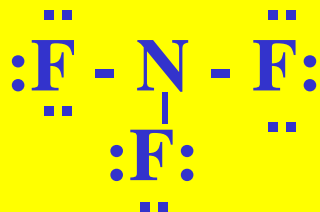


**At the end of this lesson, students should be able to :**

- (a) Explain Valence Shell Electron Pair Repulsion theory (VSEPR)**
- (b) Draw the basic molecular shapes: linear, trigonal planar, tetrahedral, trigonal bipyramidal and octahedral.**
- (c) Predict and explain the shapes of molecule and bond angles in a given species.**

# What is the actual shape of this compound?



Lewis structure



No. of e surrounding a central atom



Assumption: e pairs/bonding pair in the valence shell repel one another



Gives the position of all atoms



Study of molecular geometry



VSEPR!!

# Molecular Geometry

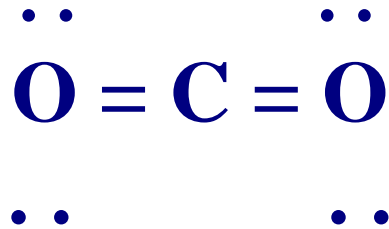
- The 3D arrangement of atoms in a molecule.
- affects physical and chemical properties.
- predicted by using **V**alence **S**hell **E**lectron **P**air **R**epulsion (**VSEPR**) model.

## What is VSEPR

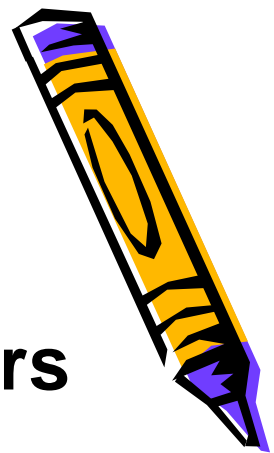
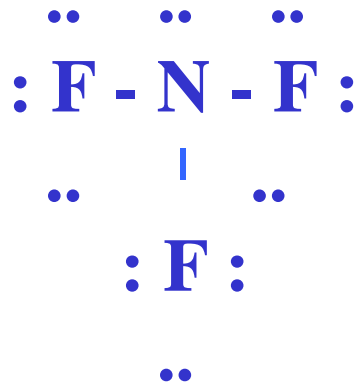
- The study of molecular geometry states “The valence electron pairs surrounding a central atom repel one another. Thus, the orbital containing those electron pairs are oriented to be as far apart as possible”.

Divide molecules into 2 categories:

- **Central atom has No Lone Pairs**



- **Central atom has  $\geq 1$  Lone Pairs**

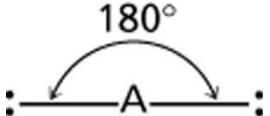
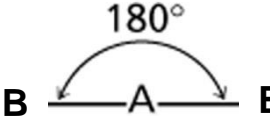


# BASIC MOLECULAR SHAPE

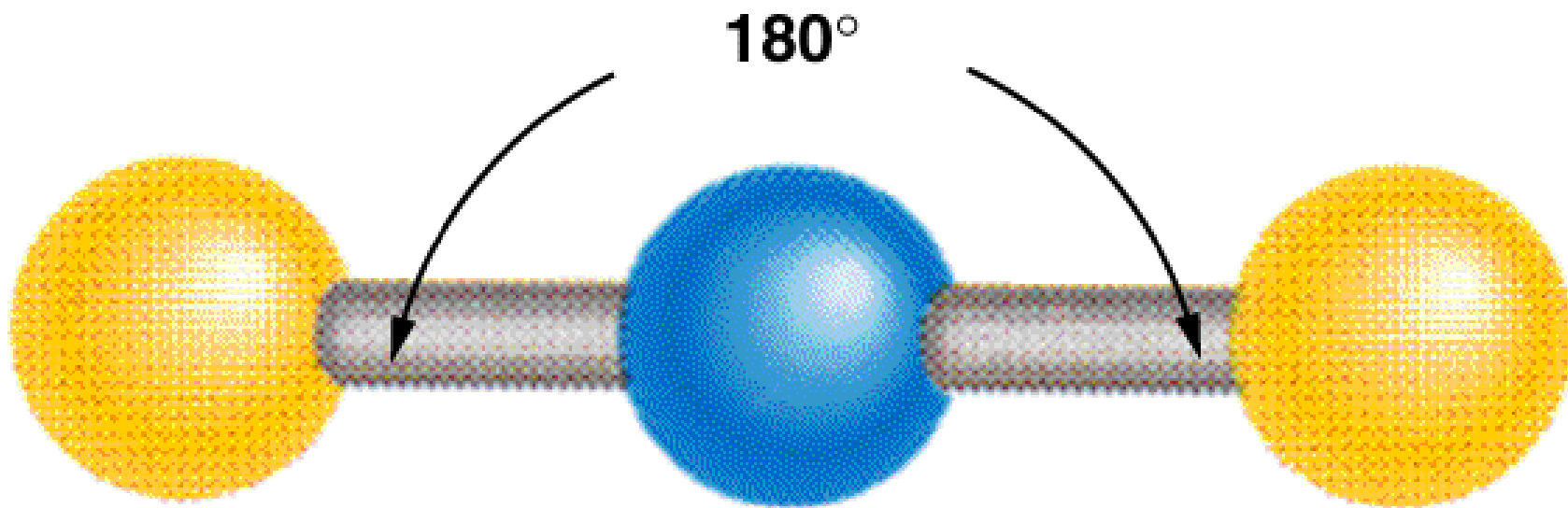
- Linear
- Trigonal Planar
- Tetrahedral
- Trigonal bipyramidal
- Octahedral



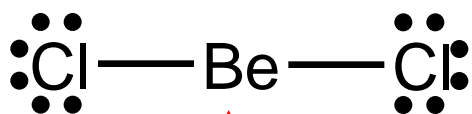
# Basic molecular shape

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
AB <sub>2</sub>	2	0	linear 	linear 

# Beryllium Chloride



- Bond angle = 180°
- Atoms arranged in a straight line
- Eg: BeCl<sub>2</sub>, HgCl<sub>2</sub>

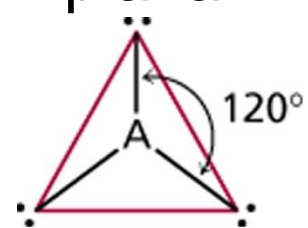


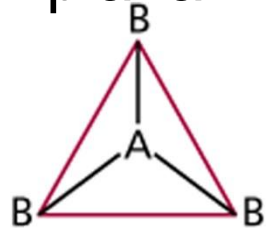
2 atoms paired to central atom



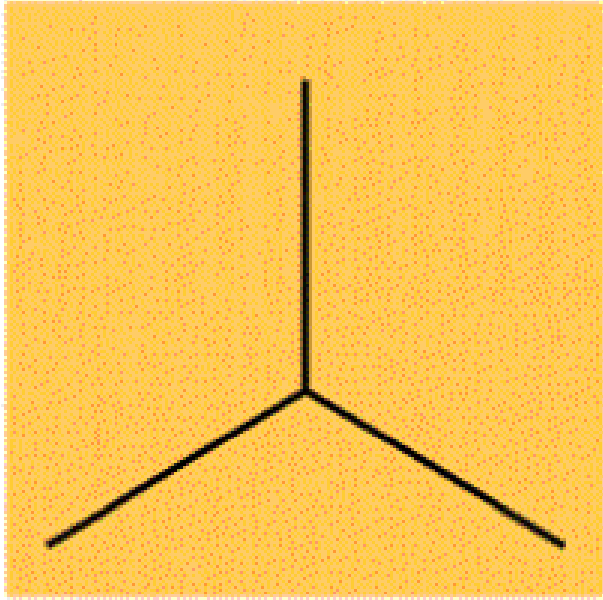
# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_2$	2	0	linear	linear
$AB_3$	3	0	trigonal planar	trigonal planar

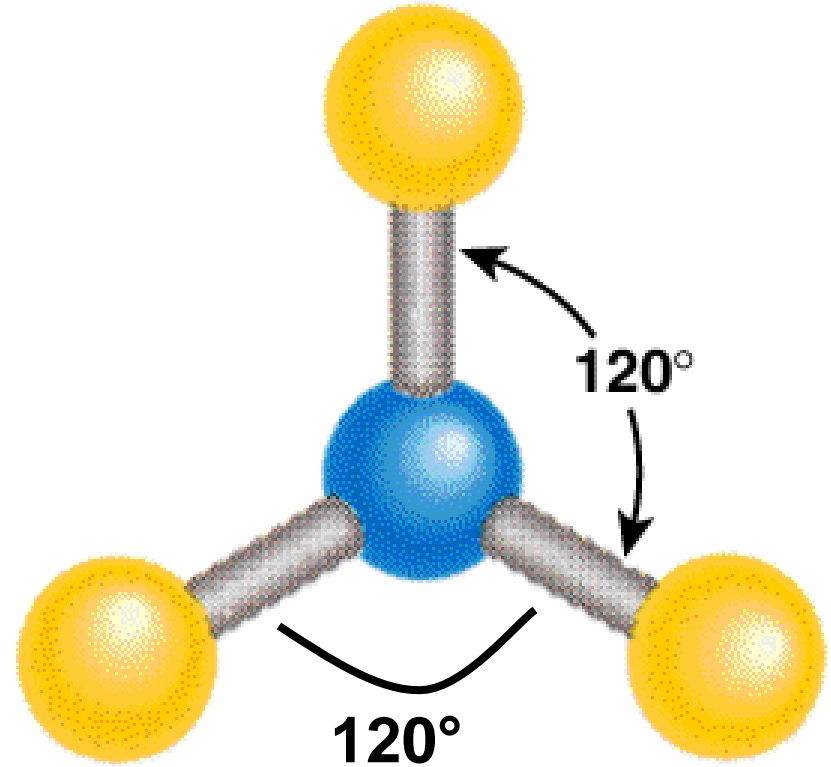




# Boron Trifluoride



**Planar**

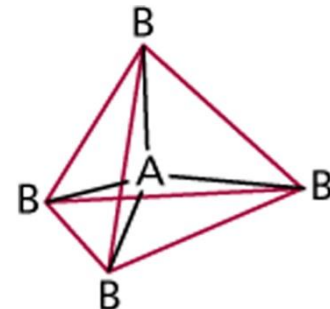
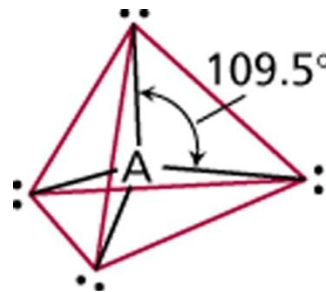


- Bond angle =  $120^\circ$
- Central atom has 3 terminal atoms
- Eg:  $\text{BF}_3$

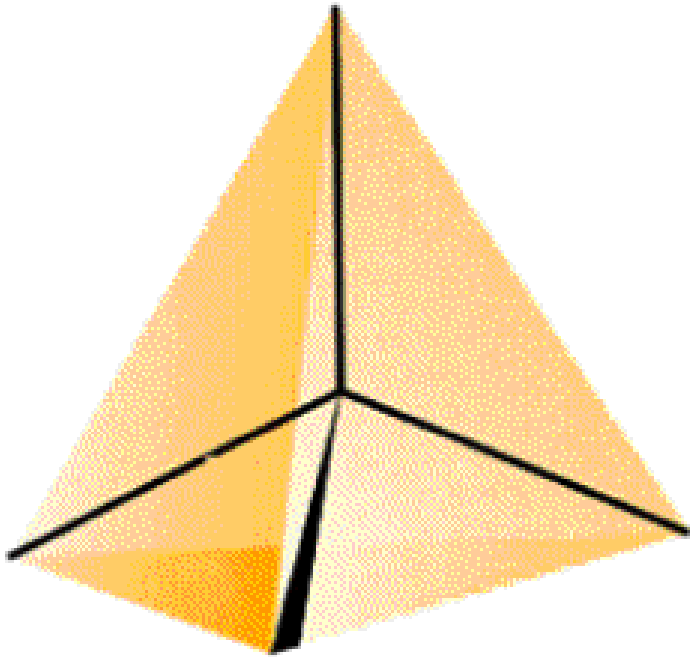


# VSEPR

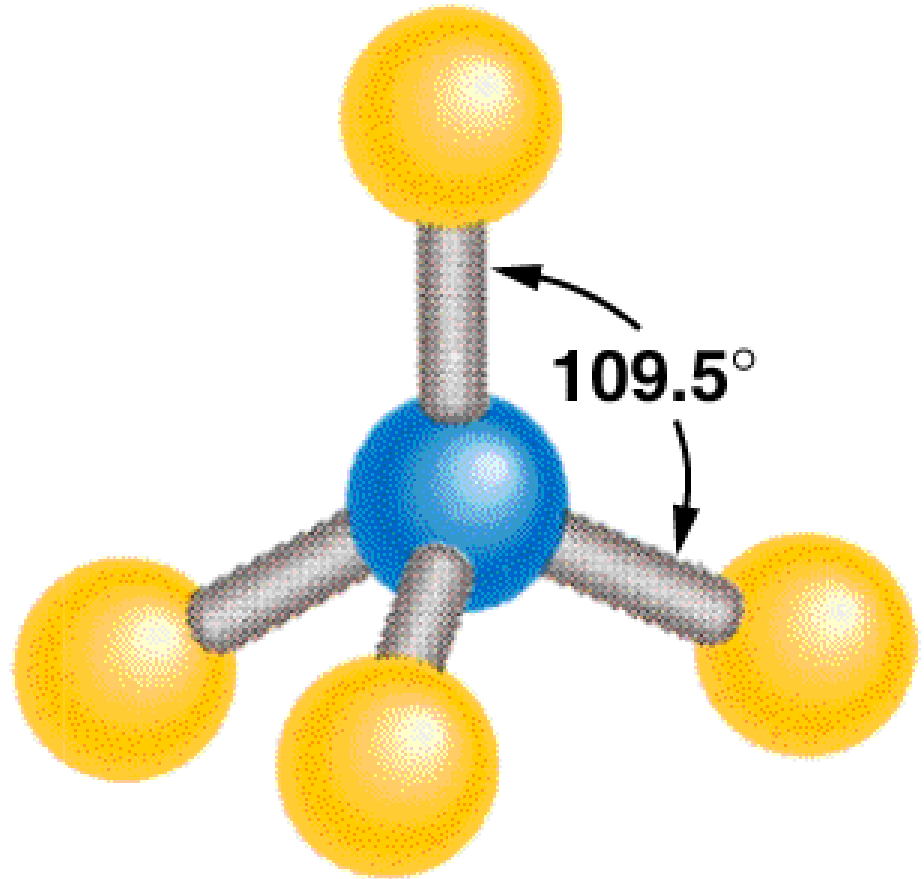
<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_2$	2	0	linear	linear
$AB_3$	3	0	trigonal planar	trigonal planar
$AB_4$	4	0	tetrahedral	tetrahedral



# Methane



**Tetrahedral**

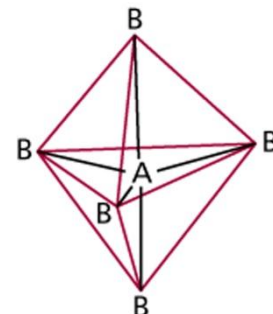
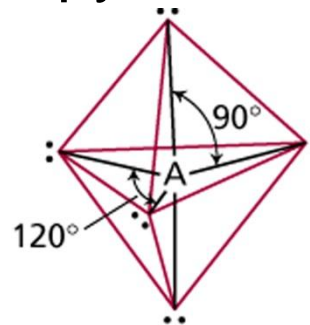


- Bond angle =  $109.5^\circ$
- Central atom has 4 terminal atoms
- Eg:  $\text{CH}_4$

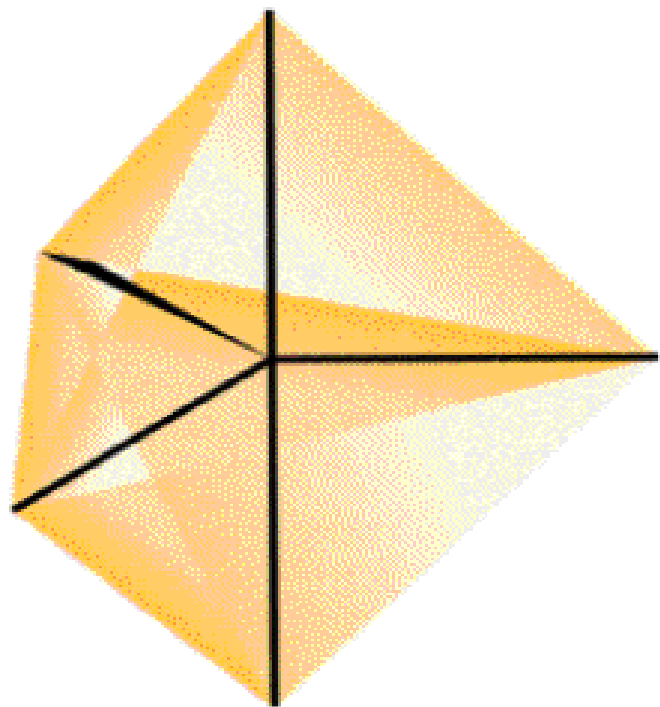


# VSEPR

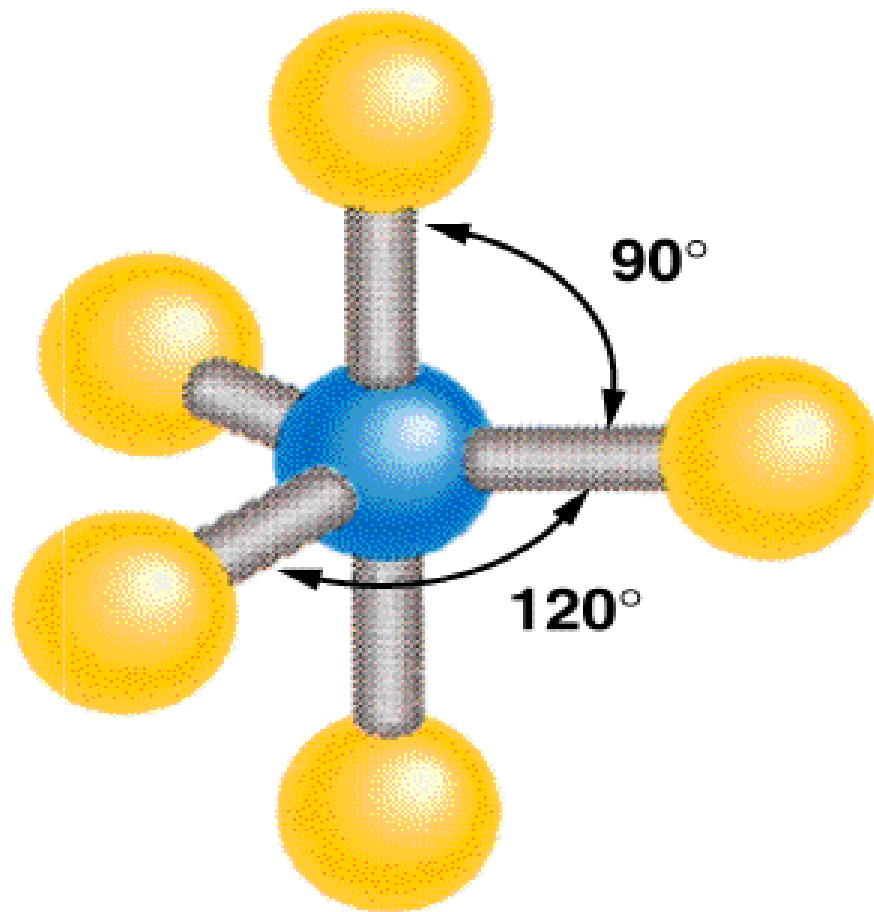
<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_2$	2	0	linear	linear
$AB_3$	3	0	trigonal planar	trigonal planar
$AB_4$	4	0	tetrahedral	tetrahedral
$AB_5$	5	0	trigonal bipyramidal	trigonal bipyramidal



# Phosphorus Pentachloride



**Trigonal  
bipyramidal**

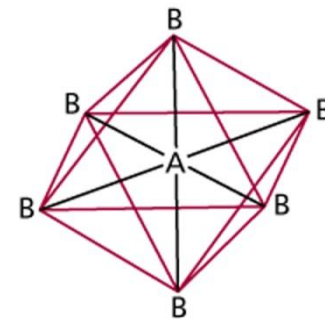
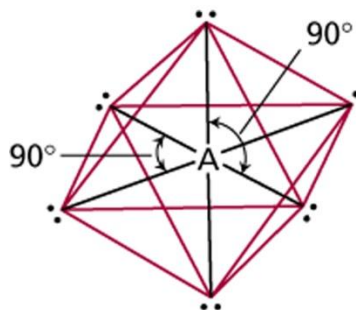


- Bond angle =  $90^\circ$ ,  $120^\circ$
- Central atom has 5 terminal atoms
- Eg:  $\text{PCl}_5$

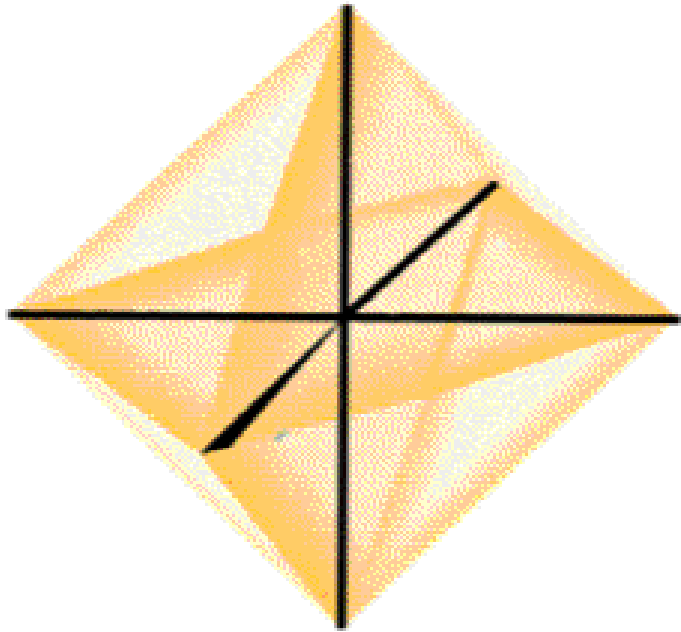


# VSEPR

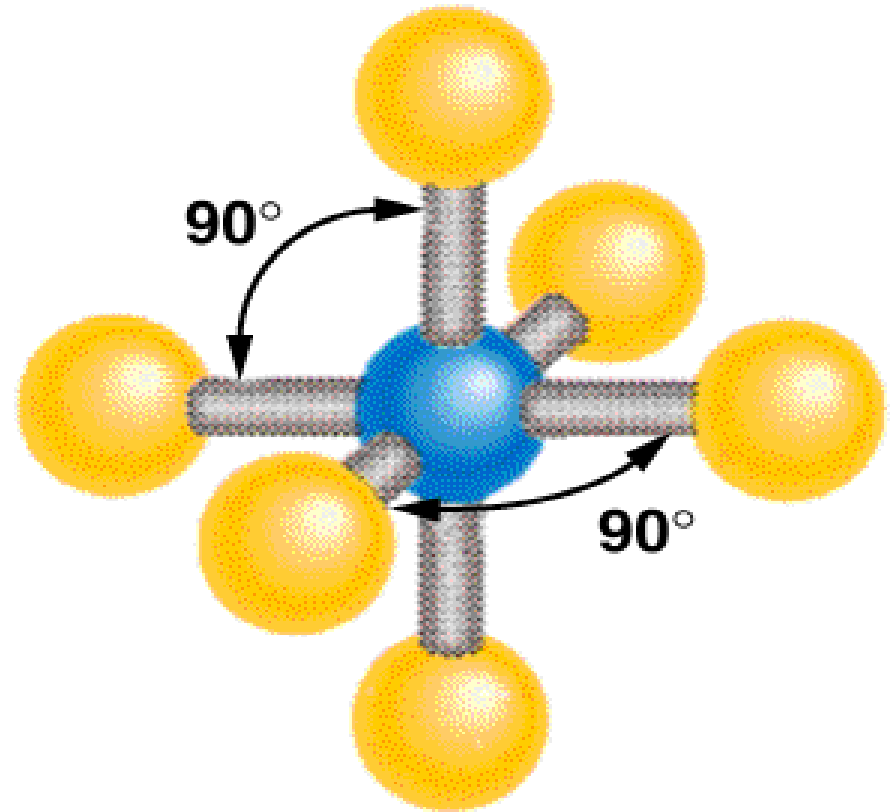
<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_2$	2	0	linear	linear
$AB_3$	3	0	trigonal planar	trigonal planar
$AB_4$	4	0	tetrahedral	tetrahedral
$AB_5$	5	0	trigonal bipyramidal	trigonal bipyramidal
$AB_6$	6	0	octahedral	octahedral



# Sulfur Hexafluoride



**Octahedral**



- Bond angle =  $90^\circ$
- Central atom has 6 terminal atoms
- Eg: XeF<sub>6</sub>

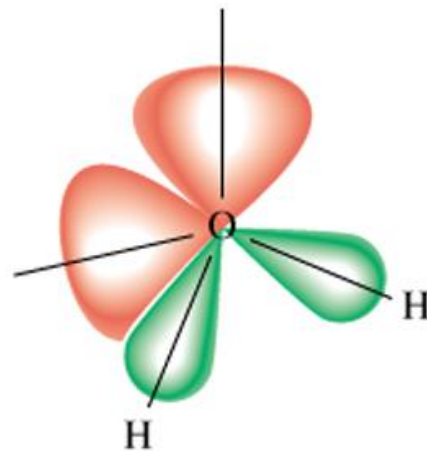
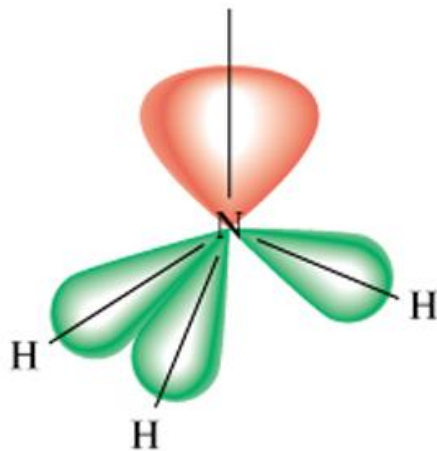
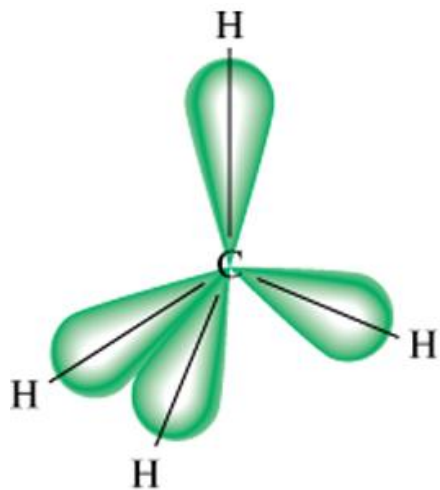


# **Molecules In Which Central Atom Has Lone Pairs**

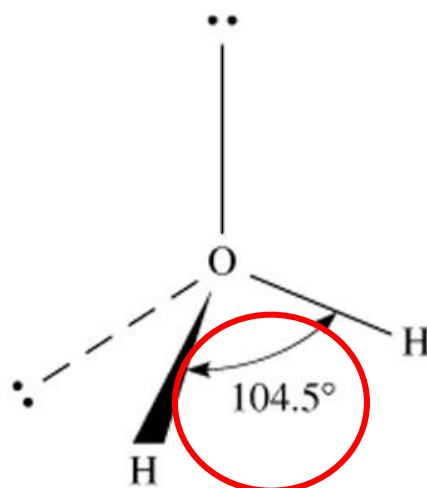
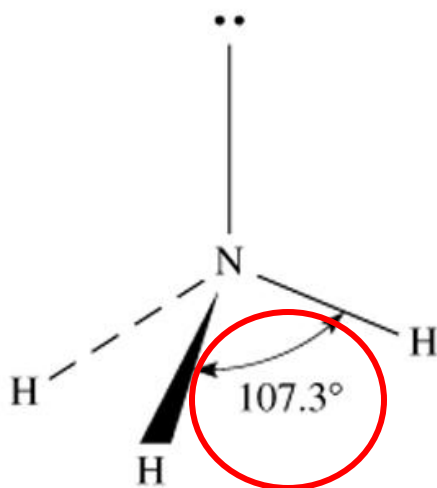
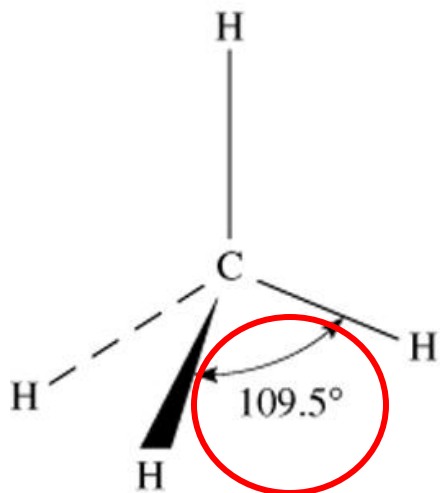
**-Geometry of molecule is more complicated if the central atom has both lone pairs and bonding pairs.**

**-3 types of repulsive forces:**

- those between bonding pairs**
- those between lone pairs**
- those between a bonding pair & lone pair**



(a)



bonding-pair vs. bonding  
pair repulsion

<

lone-pair vs. bonding  
pair repulsion

<

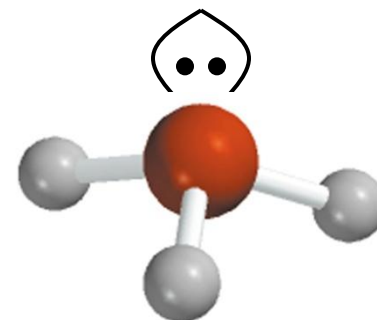
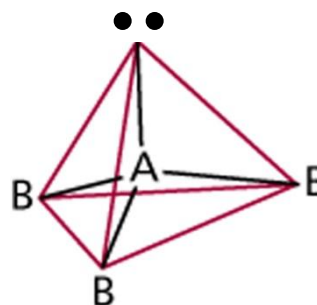
lone-pair vs. lone pair  
repulsion

# Molecules In Which Central Atom Has Lone Pairs

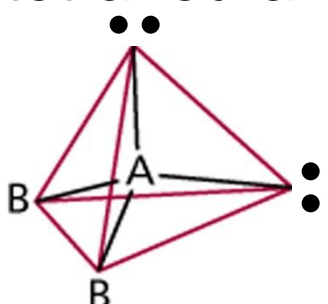
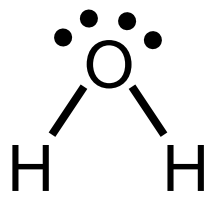
<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_3$	3	0	trigonal planar	trigonal planar
$AB_2E$	2	1	trigonal planar	<b>bent</b>

# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_4$	4	0	tetrahedral	tetrahedral
$AB_3E$	3	1	tetrahedral	trigonal pyramidal

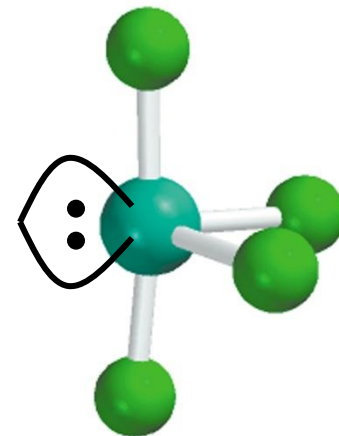
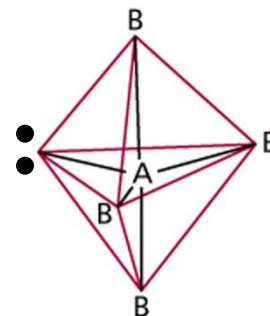


# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_4$	4	0	tetrahedral	tetrahedral
$AB_3E$	3	1	tetrahedral	trigonal pyramidal
$AB_2E_2$	2	2	tetrahedral 	<b>bent</b> 

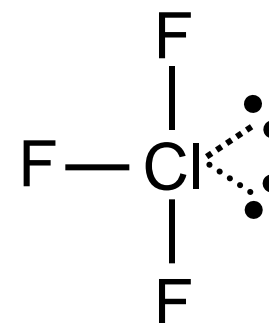
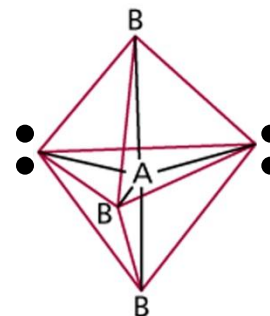
# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_5$	5	0	trigonal bipyramidal	trigonal bipyramidal
$AB_4E$	4	1	trigonal bipyramidal	distorted tetrahedron



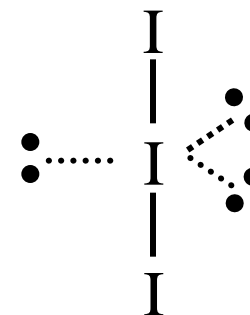
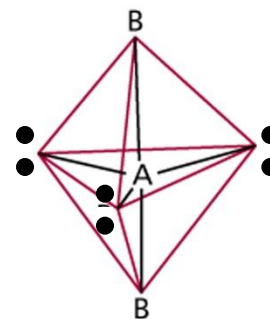
# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_5$	5	0	trigonal bipyramidal	trigonal bipyramidal
$AB_4E$	4	1	trigonal bipyramidal	distorted tetrahedron
$AB_3E_2$	3	2	trigonal bipyramidal	T-shaped



# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_5$	5	0	trigonal bipyramidal	trigonal bipyramidal
$AB_4E$	4	1	trigonal bipyramidal	distorted tetrahedron
$AB_3E_2$	3	2	trigonal bipyramidal	T-shaped
$AB_2E_3$	2	3	trigonal bipyramidal	linear

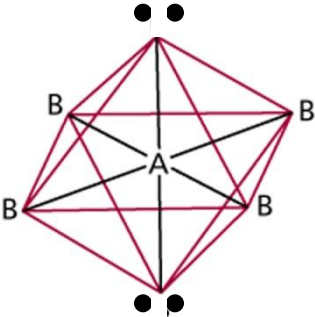


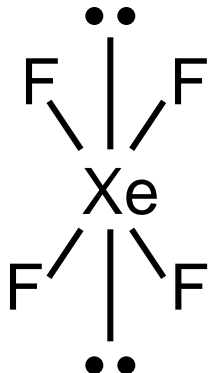
# VSEPR

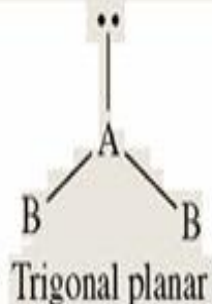
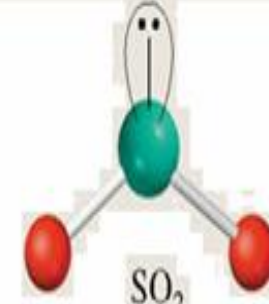

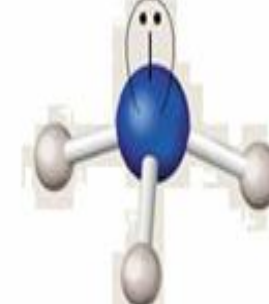


<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_6$	6	0	octahedral	octahedral
$AB_5E$	5	1	octahedral	square pyramidal

# VSEPR

<u>Class</u>	<u># of atoms bonded to central atom</u>	<u># lone pairs on central atom</u>	<u>Arrangement of electron pairs</u>	<u>Molecular Geometry</u>
$AB_6$	6	0	octahedral	octahedral
$AB_5E$	5	1	octahedral	square pyramidal
$AB_4E_2$	4	2	octahedral	square planar





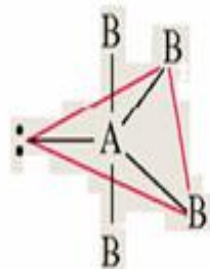
Class of molecule	Total number of electron pairs	Number of bonding pairs	Number of lone pairs	Arrangement of electron pairs	Geometry	Examples
$AB_2E$	3	2	1	 <p>Trigonal planar</p>	Bent	 <p><math>SO_2</math></p>
$AB_3E$	4	3	1	 <p>Tetrahedral</p>	Trigonal pyramidal	 <p><math>NH_3</math></p>
$AB_2E_2$	4	2	2	 <p>Tetrahedral</p>	Bent	 <p><math>H_2O</math></p>

$AB_4E$ 

5

4

1



Trigonal bipyramidal

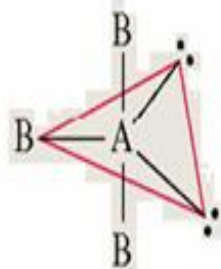
Distorted tetrahedron (or seesaw)

 $SF_4$  $AB_3E_2$ 

5

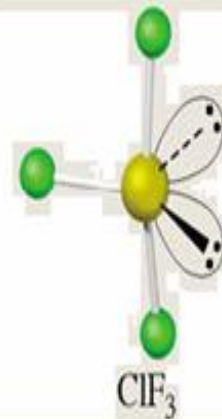
3

2



Trigonal bipyramidal

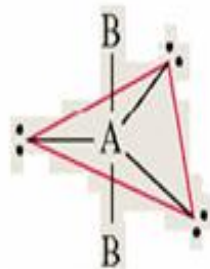
T-shaped

 $ClF_3$  $AB_2E_3$ 

5

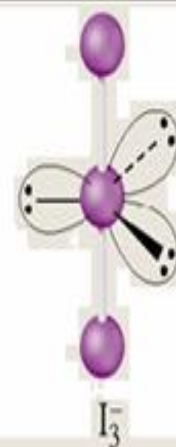
2

3



Trigonal bipyramidal

Linear

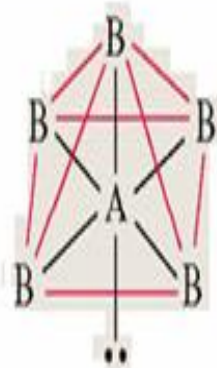
 $I_3^-$



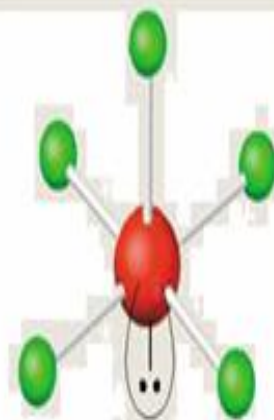
6

5

1



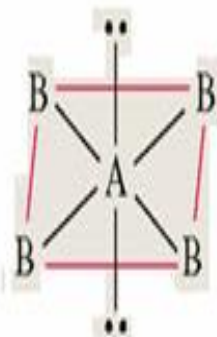
Octahedral

Square  
pyramidal $BrF_5$ 

6

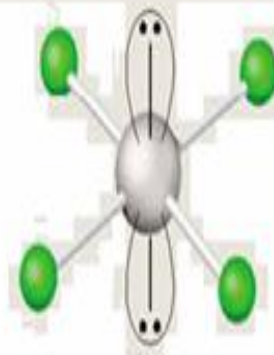
4

2



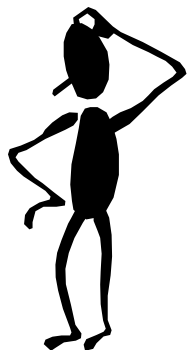
Octahedral

Square planar

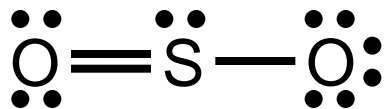
 $XeF_4$

# Predicting Molecular Geometry

1. Draw Lewis structure for molecule.
2. Count number of **lone pairs on the central atom** and **number of atoms bonded to the central atom**.
3. Use VSEPR to predict the geometry of the molecule.

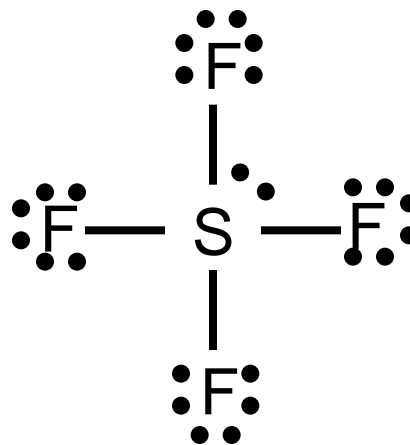


e.g.: What are the molecular geometries of  $\text{SO}_2$  and  $\text{SF}_4$ ?



$\text{AB}_2\text{E}$

bent



$\text{AB}_4\text{E}$

distorted  
tetrahedron

## Excercise:

Use the VSEPR model to predict the geometry of the following molecules and ions:

