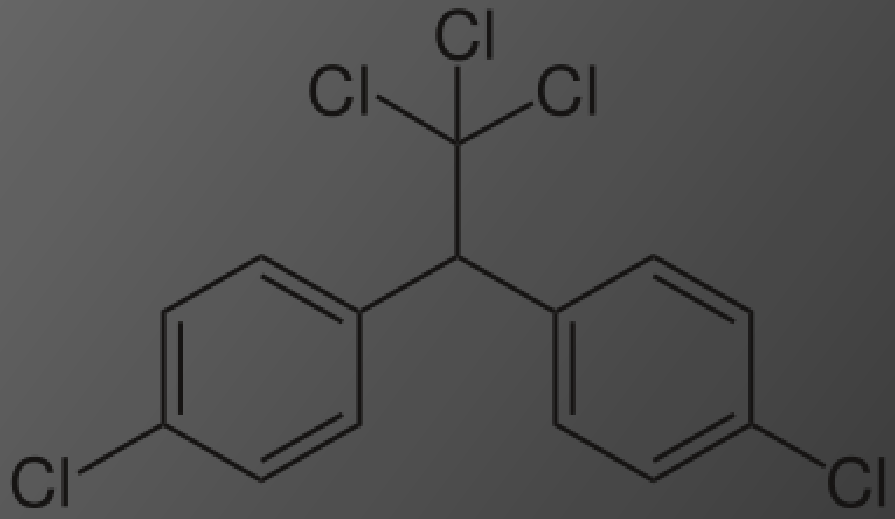
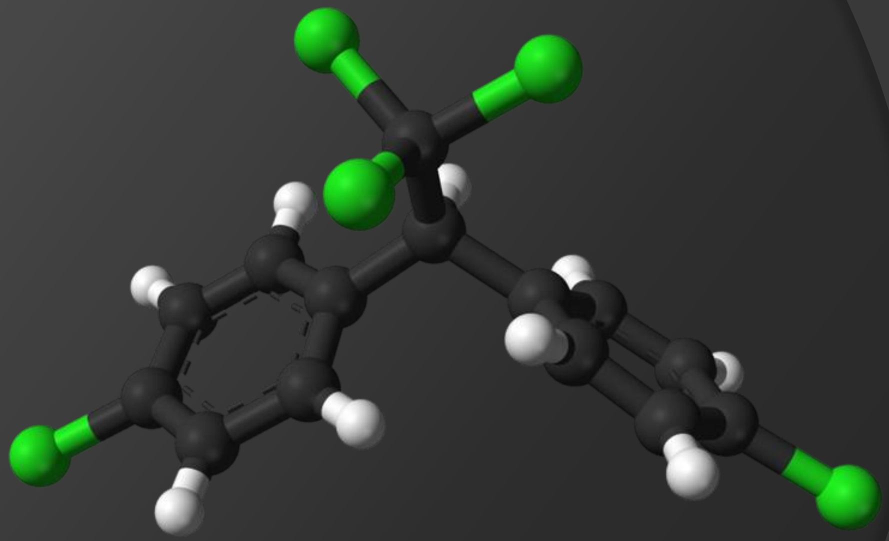
MOLECULAR SHAPES





Chemistry

Karl Steffin, 2010

8/14/2025

By end of this unit I can...

NP1: identify the four fundamental forces and describe applications of these processes.

CB4: draw a Lewis Dot Structure for any element in family 1-8.

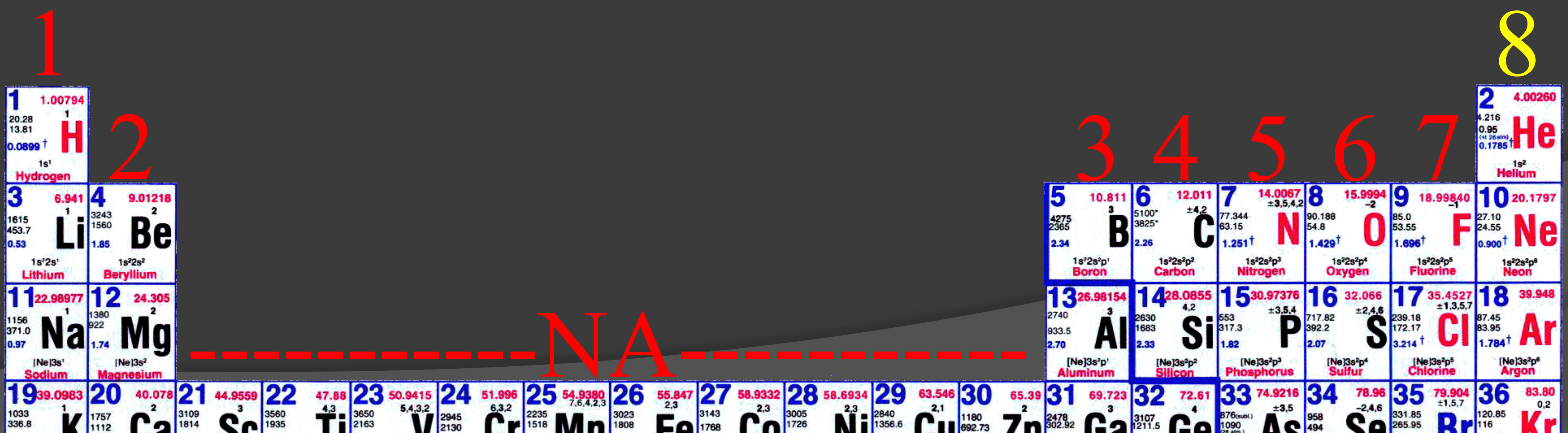
CB5: use the Lewis Dot Structure to explain the diagram and the geometric shape of a molecule.

CB6: use the geometric shape and periodic table to determine a molecules polarity.

CB7: state the importance of attractive forces (Hydrogen bonding, Van Der Walls).

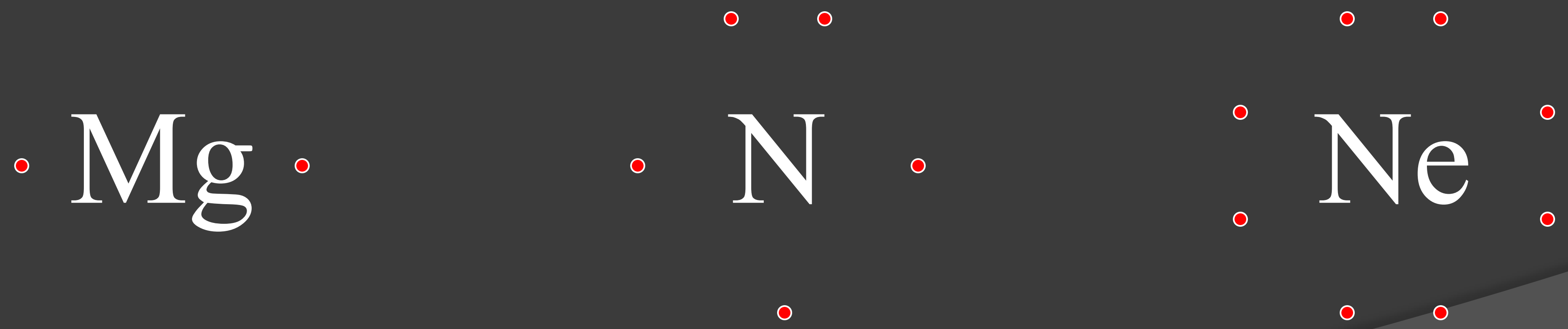
More about Electron’s

- A more simplified way to look at electrons is to look at their Lewis Dot Structures.
- This counts the atoms in the highest energy level (so only count the s and p e^-).
  - This also relates to the family #



Lewis Dot Structures

- Mg ($12p^+$): $1s^2 2s^2 2p^6 3s^2$.
- N ($7p^+$): $1s^2 2s^2 2p^3$.
- Ne ($10p^+$): $1s^2 2s^2 2p^6$.



Rule 1: 1 e^- side first.
Rule 2: Balanced sides if possible.
Rule 3: Max $2e^-$ per side.

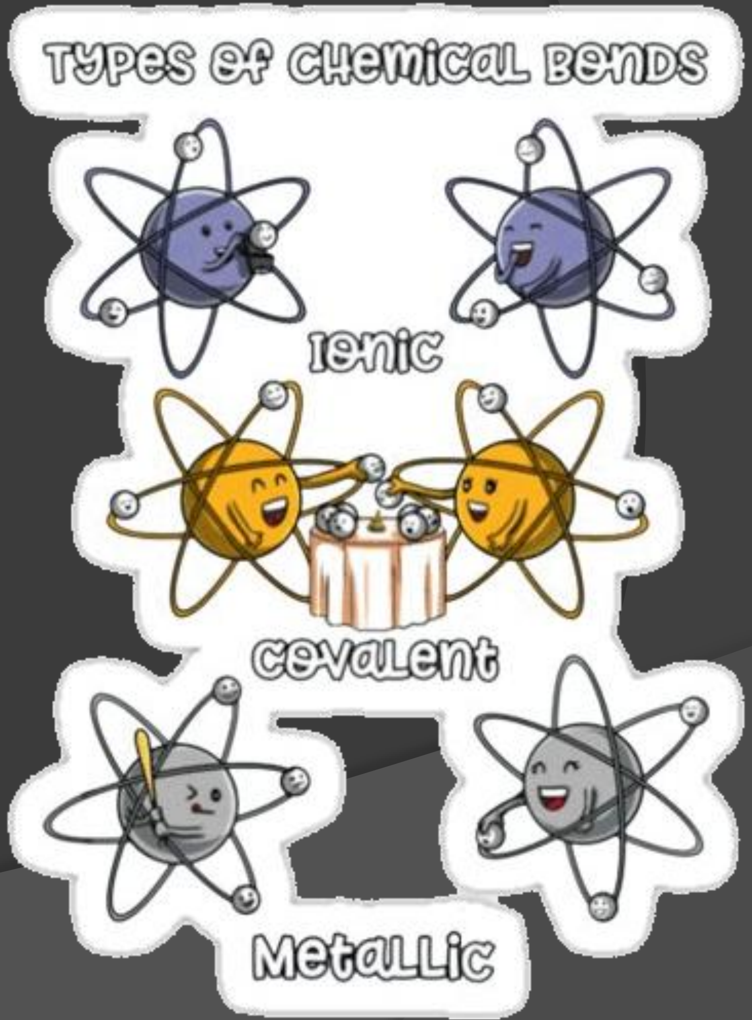
For Nobel Gasses…
Draw all 8 (2 for He)

Review Plus New

- Bonding revolves around the e^-.
- e^- in the outer shell are called **valence e^-**.
  - The exception is if the outer shell is complete, the Nobel Gases have 0 valence e^-.
- All atoms want to have complete shells.
  - A little saying: All elements aspire to be Nobility!

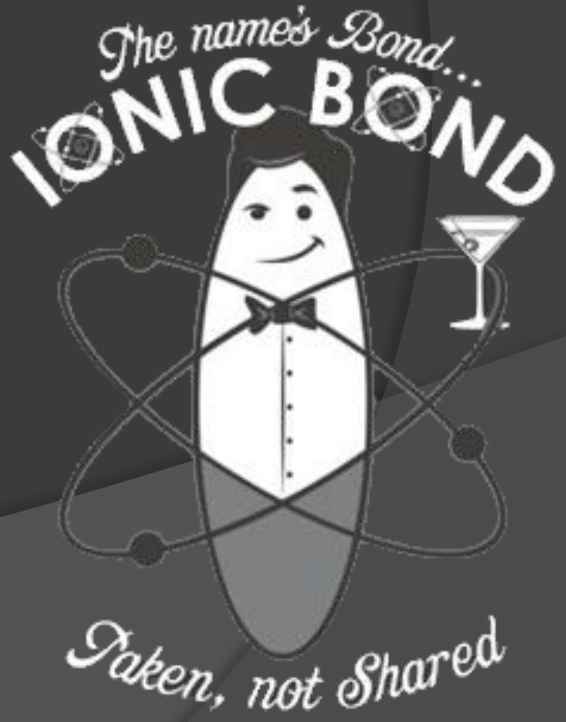
Bonding

- Bonding is the process of two or more atoms joining chemically to form a new product.
- Bonding is very common and has three forms:
  - Ionic
  - Covalent
  - Metallic



Ionic Bonding

- Ionic bonding involves positive ions joining negative ions.
- Looking at the periodic table positive ions are on the left and negative ions on the right.
- So… basic Ionic bonding involves metal/ non-metal bonding.

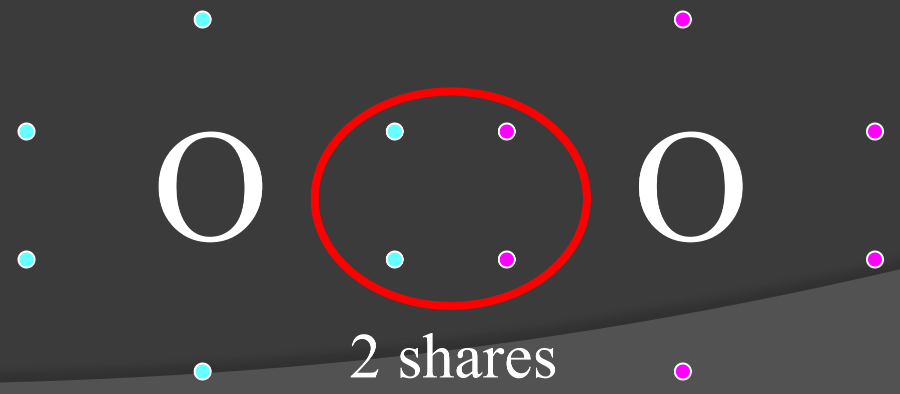


Why Ionic Bonds Happen

- Look at a common ionic bond: NaCl.
  1. Draw The Lewis Structure for Na and Cl.
  2. Cl is missing 1, Na has 1 extra. Na gives up 1.
  3. The metal Na^{+} ion and non-metal Cl^{-} ion attract.
- Completing Energy levels makes this is a very strong bond.

Covalent Bonding

- Another way an atom may have complete energy levels is to share.
- This happens when an atom needs one to three electrons to be complete. (Fam: 5-7)
- Looking at the periodic table these elements they are non-metals.
- Covalent Bonding is non-metal/non-metal bonding.



Molecular Shapes

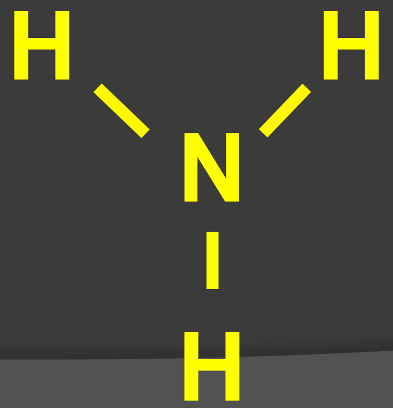
- Depending on how individual elements bond to each other also determines their molecular shape.
- For two elements/atoms bonded together there is only one shape: Linear.

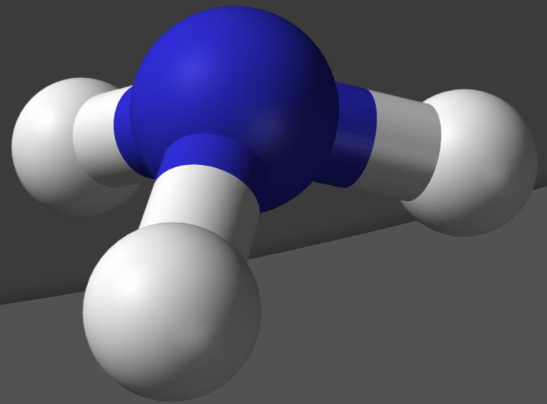
$$F_2 \longrightarrow F - F$$

- More complicated shapes are formed when multiple elements/atoms bond.

VSEPR Theory

- When covalent bonds are formed they create slight charges (remember electrons want to repel).
- The **V**alence **S**hell **E**lectron **P**air **R**epulsion Theory helps to determine the shape of these molecules.
- Here is shown the structural model and the stick and ball model of Ammonia (NH_3).





Algorithm to Solve VSEPR Shapes

- Pairs of electrons that surround the central atom of a molecule or ion are arranged as far apart as possible to minimize repulsion.
- To predict the shapes of molecules, follow these steps:

1. Decide which is the central atom in a molecule. Normally the lone element or the first written.

VSEPR Algorithm cont.

2. Count up the valence electrons around the central atom.
3. Count up the electrons needed by the outer atom(s) to become complete.
4. Add the numbers in step 2 + 3 then divide by two to get the Valence Shell Electron Pair (VSEP) number.
   - If step 3 requires more than one bond (Outer element is Family 4-6.); subtract one from the VSEP count for each extra bond beyond the first.

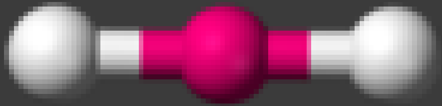
- This VESP number is the Native Shape.

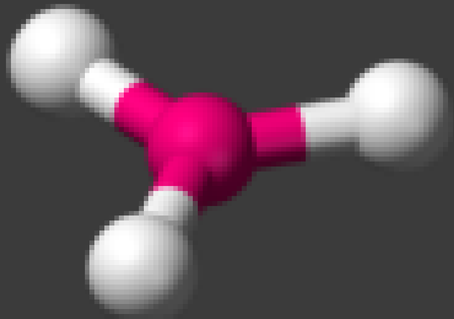
VSEPR Algorithm cont.

5. Using the number in step 3 cross out that many electrons around the central atom. (cross out single electron first)
   - Circle any pairs still remaining.
   - These are called Lone Pairs and will warp the Native Shape.
6. Look at the VSEP chart to find the new warped shape.
7. Draw a model of the molecule.

Native VSEPR Predictions

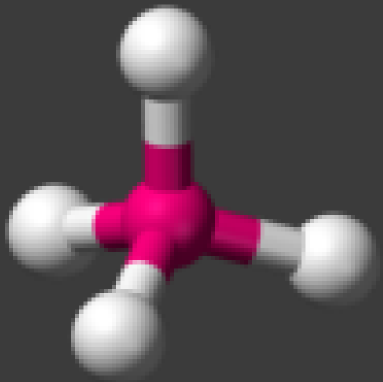
2 Linear

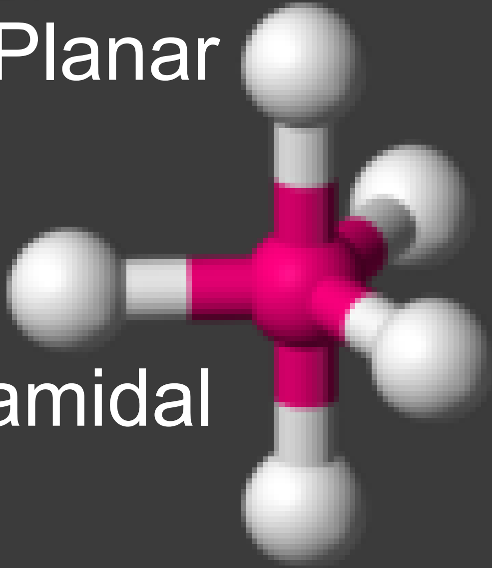




3 Trigonal Planar

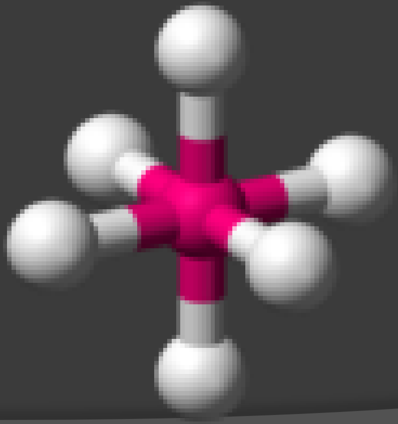
4 Tetrahedral

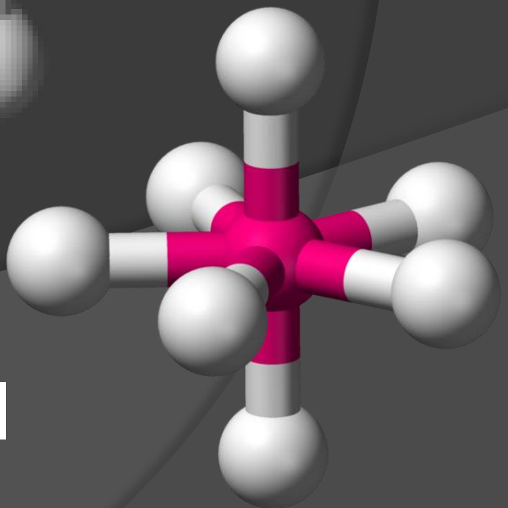




5 Trigonal Bipyramidal

6 Octahedral



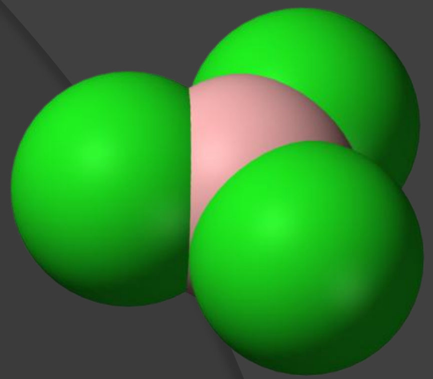


7 Pentagonal Bipyramidal

Native and Warped Predictions

VSEP #	Native Shape	1 Lone Pair	2 Lone Pair	3 Lone Pair
2	Linear			
3	Trigonal Planar	Bent		
4	Tetrahedral	Trigonal Pyramidal	Bent	
5	Trigonal Bipyramidal	Seesaw	T Shaped	Linear
6	Octahederal	Square Pyramid	Square Planar	
7	Pentagonal Bipyramidal	Pentagonal Pyramidal		

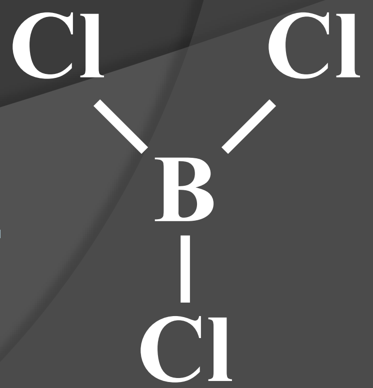
Example



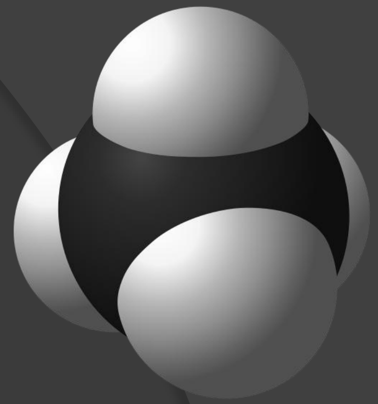
- BCl_3 1. Central Atom: B

2. B Valence: 3, 3. Cl Needed: 1 x 3
4. (2.+ 3.)/2 3 + 1 x 3 = 6 / 2 = 3
5. Basic Shape: Trigonal Planar
6. Cross out 1 x 3 around Boron. Circle pairs (0).
7. The basic shape holds… Trigonal Planar

7.

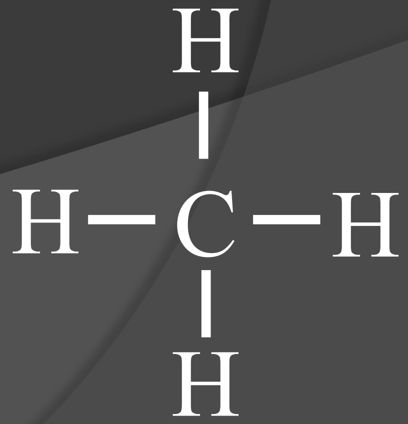


Example

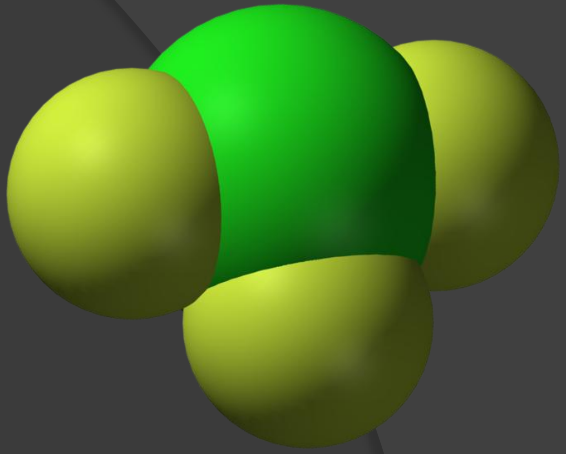


- CH_4 Central Atom: C

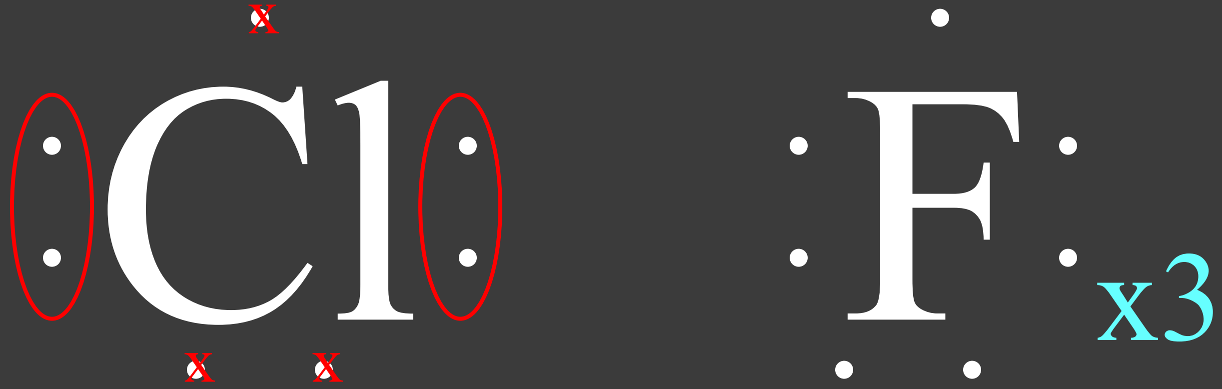
- C Valence: 4, H Needed: 1 x 4
- 4 + 1 x 4 = 8 / 2 = 4
- 4 Basic Shape: Tetrahedral
- Cross out 1 x 4 around Carbon. Circle pairs (0).
- The basic shape holds... Tetrahedral



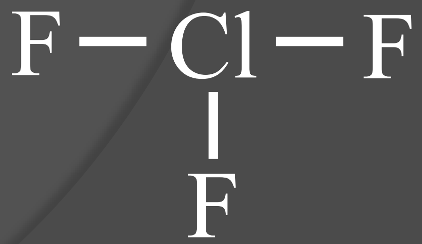
Example



- ClF_3 Central Atom: Cl



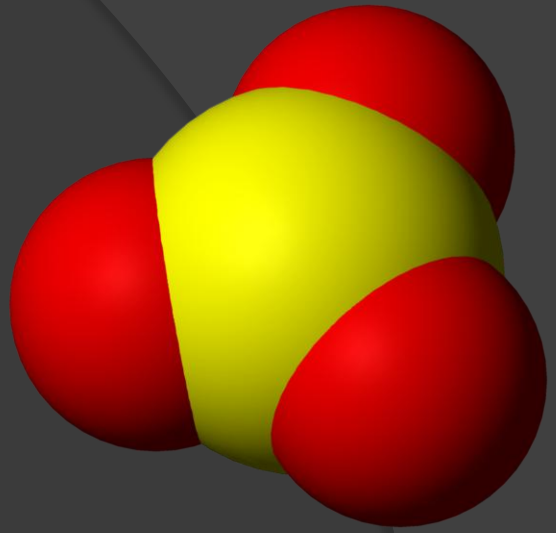
- Cl Valence: 7, F Needed: 1 x 3
- 7 + 1 x 3 = 10 / 2 = 5
- 5 Basic Shape: Trigonal Bipyramidal
- Cross out 1 x 3 around Chlorine. Circle pairs (2).
- The basic shape warps... T Shaped



Multiple Bonds (Outer Elements)

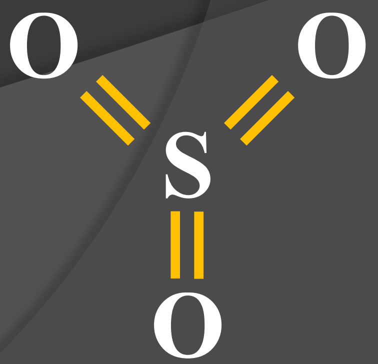
- Some elements need to have more than a single bond when not the central atom.
  - Oxygen (Family VI) creates double bonds. =
  - Nitrogen (Family V) creates triple bonds. ≡
- When doing VSEP math add step 2 and 3 divide by two as always then…
  - Subtract 1 from the total for every additional bond. [(Step 3 – 1) x outer elements]
  - This new number is the Native Shape.

Example

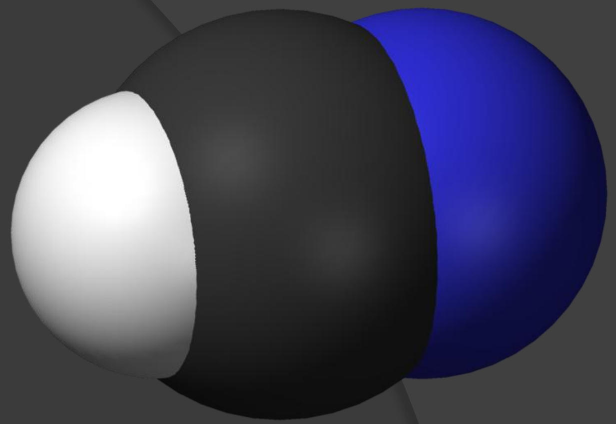


- SO_3 Central Atom: S

- S Valence: 6, O Needed: 2 x 3
- 6 + 2 x 3 = 12 / 2 = 6 - (2-1) x 3 = 3
- 3 Basic Shape: Trigonal Planar
- Cross out 2 x 3 around Sulfur. Circle pairs (0).
- The basic shape holds… Trigonal Planar



Example



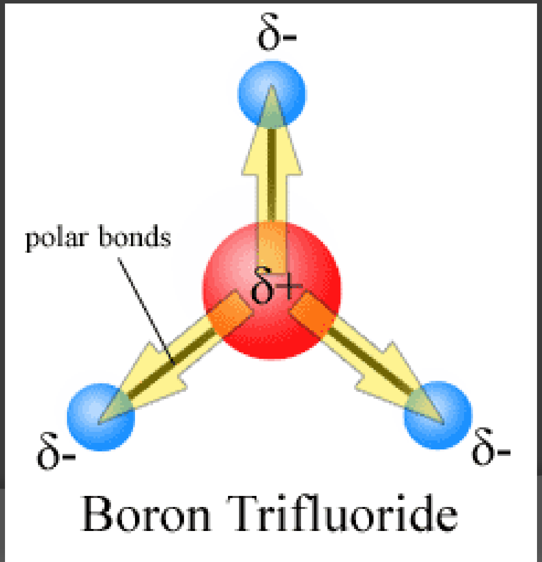
- HCN Central Atom: C

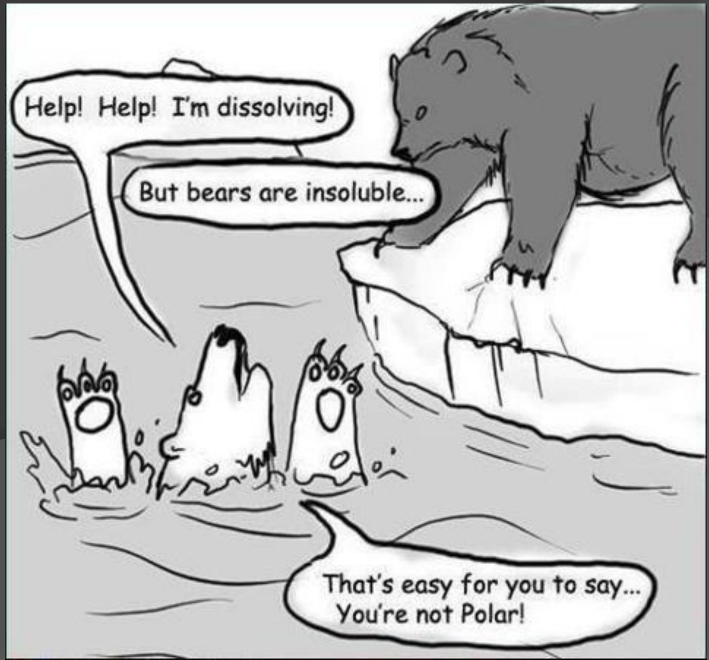
- C Valence: 4, H Needed: 1 x 1 N Needed: 3 x 1
- 4 + 1 x 1 + 3 x 1= 8 / 2 = 4 - (1-1)x1 - (3-1)x1= 2
- 2 Basic Shape: Linear
- Cross out 1 + 3 around Carbon. Circle pairs (0).
- The basic shape holds... Linear

$H-C\equiv N$

Polarity

- Electrons are not always shared equally.
- Elements that pull electrons toward them are considered electronegative.
- This causes molecules to be formed with a polarity (much like a magnet).





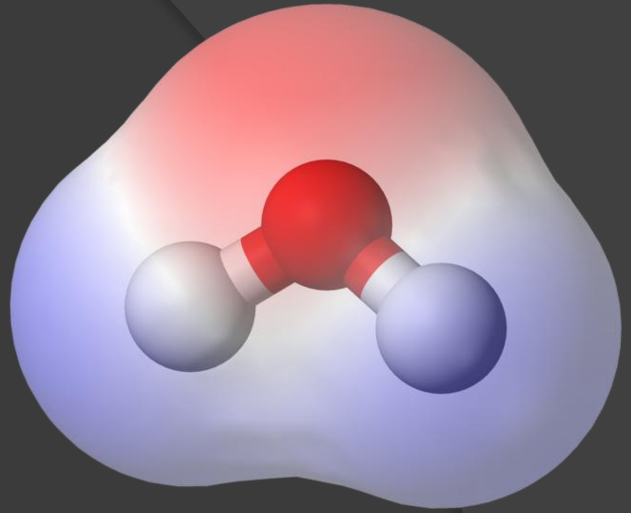
Polarity chart

Electronegativity difference	Bond Type
$X \leq 0.4$	(Non-Polar) Covalent
$.4 \leftrightarrow 2.0$	Polar Covalent
$X \geq 2.0$	Completely Polar 'Ionic'

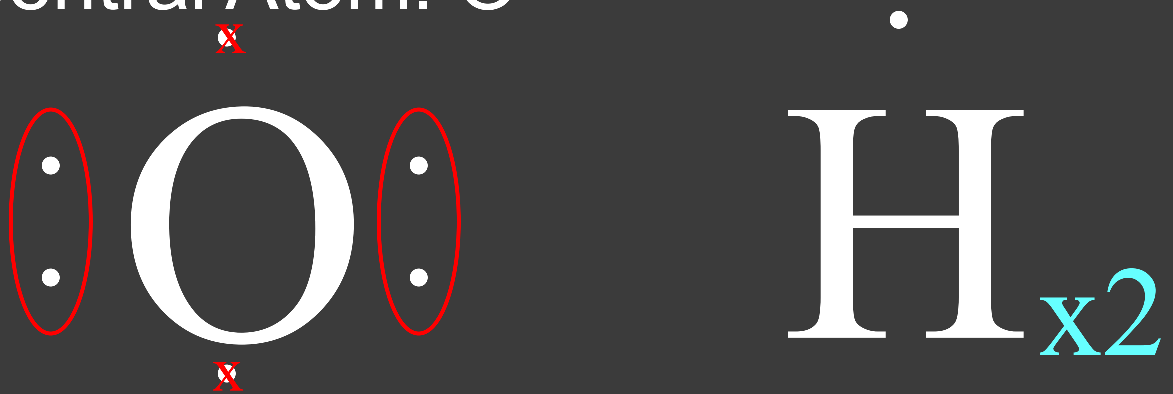
- Ex: HCl- Hydrogen: 2.20, Chlorine: 3.16
  - 3.16-2.20 = .96 (Polar Covalent)
- Ex: NO_2- Nitrogen: 3.04, Oxygen: 3.44
  - 3.44-3.04 = .40 (NP Covalent)
- Ex: NaCl- Sodium: .93, Chlorine: 3.16
  - 3.16-.93 = 2.23 (Completely Polar… Ionic)

Electronegativity (Pauling Scale)		
Z	Sym	Magnitude
1	H	2.2
2	He	
3	Li	0.98
4	Be	1.57
5	B	2.04
6	C	2.55
7	N	3.04
8	O	3.44
9	F	3.98
10	Ne	
11	Na	0.93
12	Mg	1.31
13	Al	1.61
14	Si	1.9
15	P	2.19
16	S	2.58
17	Cl	3.16
18	Ar	

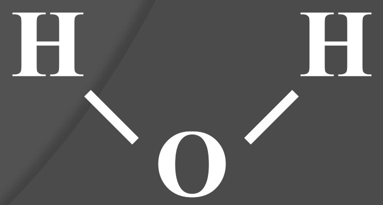
Example



- H_2O Central Atom: O

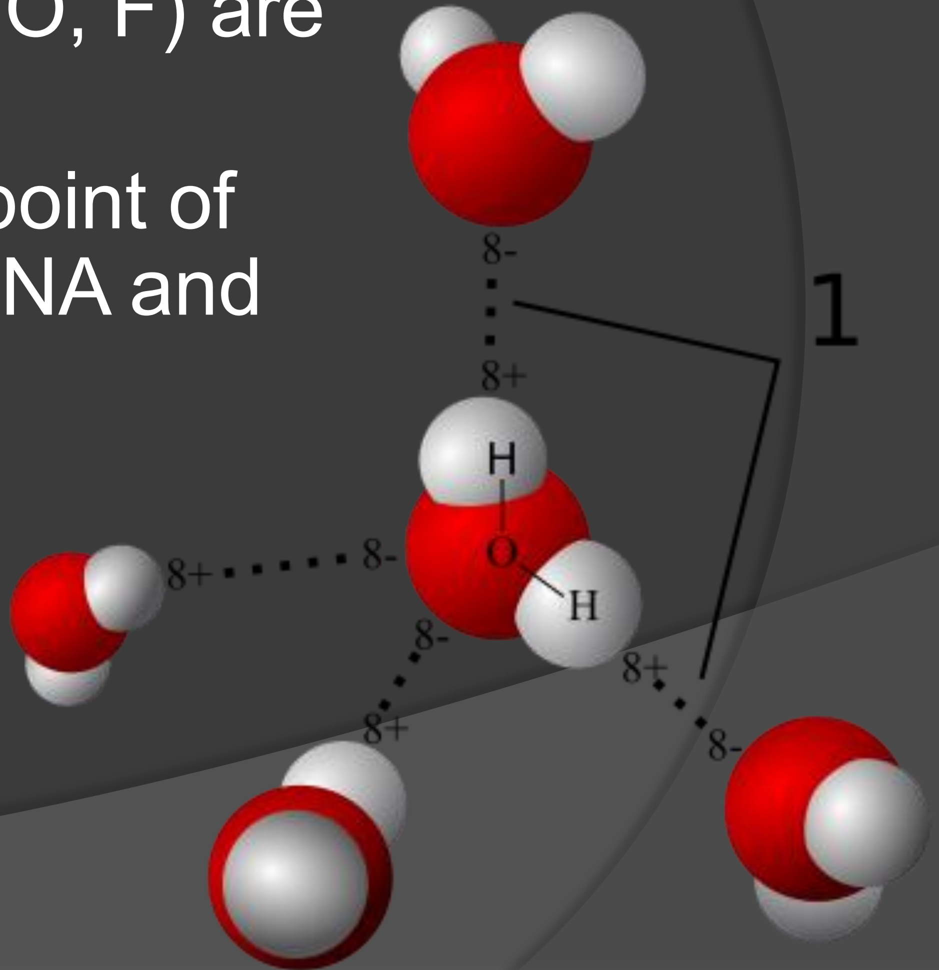


- O Valence: 6, H Needed: 1 x 2
- 6 + 1 x 2 = 8/2 = 4
- **4 Basic Shape: Tetrahederal**
- **Cross out 1 x 2 around Oxygen. Circle pairs (2).**
- **The basic shape warps… Bent**
- **Polarity Check: O: 3.44 - H: 2.20 = 1.24 (Polar Covalent)**



Hydrogen Bonds

- When polar molecules that contain Hydrogen and a strong electronegative atom (N, O, F) are together they attract
- This is the reason for the high boiling point of water and the structure of polymers, DNA and proteins.



Van der Waals Forces

- A final type of weak attraction not yet discussed is called Van der Waals Forces.
- This is a weak force of attraction between molecules or atoms due to a temporary electrical charge.
- This is a partial reason why geckos can climb shear surfaces.
- Materials are being developed to replicate this behavior. (MI:4)

Johannes D. van der Waals (1837-1923)

Metallic Bonding

- **Metals don't have enough e^- to share, and don't have a set order to give up e^-.**
  - **They repeat to form crystal lattices.**
- **These atoms have strong attractive forces.**
  - **This is why they have high melting points.**
- **Individual atoms are thought to have nuclei like islands with the outer electrons swimming around them.**
  - **This is why they are also conductors.**

What Keeps it All Together

- There are four fundamental forces of nature.
  - Gravity: A non-contact force of mutual attraction between two masses.
  - Electromagnetism: A non-contact force resulting from the interaction of charged particles.
  - Strong Interaction: An attractive force that binds neutrons and protons together, or smaller particles together.
  - Weak Interaction: Responsible for the existence and structure of atomic nuclei, and both radioactive decay and nuclear fusion.

Strength of Bonds

- Covalent
  - Bonds can branch and form chains (polymers)
  - Good inductors
- Ionic
  - Strongest bonds
  - Superior inductors
- Metallic
  - Malleable and Ductile
  - Superior conductors