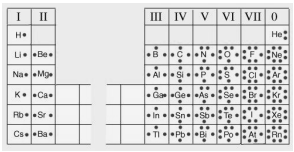
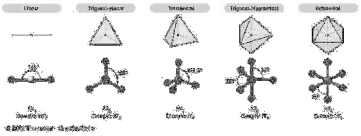


# Lewis Dot Formulas



Na [Ne] $3s^1$

F [He] $2s^2 2p^5$



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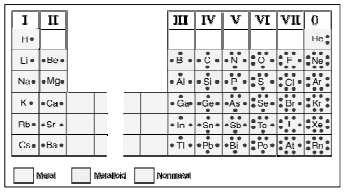
## Lewis Dot Formulas

**Gilbert Lewis (1916)**
**Valence electrons represented by dots around a core**
**Elements have "A" group number of valence electrons**

**Tool for explaining bonding between atoms**




**Members of a Chemical Family have same Lewis Dots**



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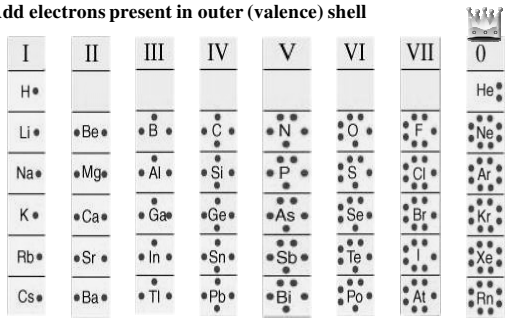
## Lewis Dot Formula - Atoms

**Start with element symbol**
**Add electrons present in outer (valence) shell**



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## Octet Rule

**Eight valence electrons, $ns^2np^6$, is especially stable**
**Noble gases do not tend to form compounds**

**To reach stability of the octet:**
**Atoms lose or gain (transfer) electrons (for ionic compounds)**
**Atoms share electrons (for molecular or covalent bonded compounds)**


**Product: both atoms with "inert configuration"**



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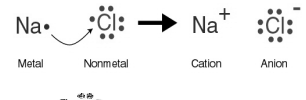
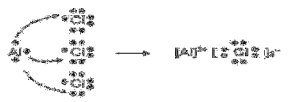
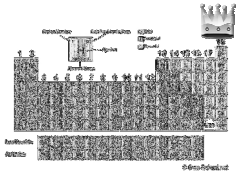
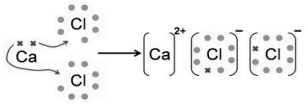
## Lewis Dot Formula – Ionic Compounds

**Electrons transferred from metal to non-metal**







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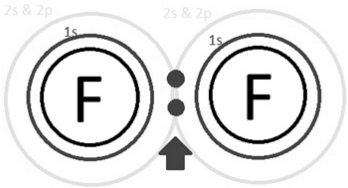
## Covalent Bond: Electrons Shared




**Electron pair BETWEEN atoms implies sharing**
**Both atoms "noble"**
**Each shared pair = covalent bond**



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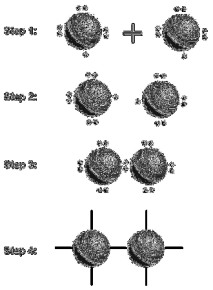
## Nomenclature – Line for pair
## Example: Diatomic Halogen




**Draw Valence Electrons**

**Establish "share" or "transfer"**

**Connect "Share"**

**Can replace any 2 $e^-$ with line**



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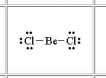
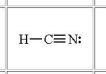
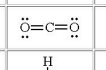
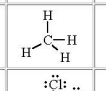
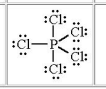
## Lewis Dot Formula - Compounds

| molecule | Lewis structure | # regions of high electron density | molecule | Lewis structure | # regions of high electron density |
|---|---|---|---|---|---|
| $BeCl_2$ |  | 2 | $BF_3$ |  | 3 |
| HCN |  | 2 | $SO_3$ |  | 3 |
| $CO_2$ |  | 2 | $NO_2$ |  | 3 |
| $CH_4$ |  | 4 | $NH_3$ |  | 4 |
| $PCl_5$ |  | 5 | $SF_6$ |  | 6 |



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## Lewis Dot Formulas

**Useful for simple ions**
**Rapidly becomes tedious**
**Typically, does Not provide stereochemistry**

**Ammonia**

**Chemistry is a 3-D Phenomenon**
**2-D thinking limits horizons & understanding**



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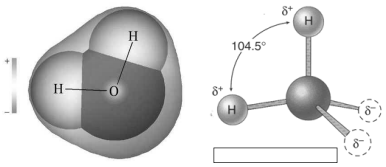
## Valence Shell Electron-Pair Repulsion
## VSEPR ("Ves-per")

**Unshared Pairs Repel – maximize distance between pairs**
**Creates Molecular Geometry**




**Extension of Lewis Dot Structures**



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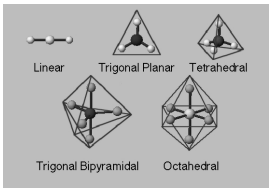
## Valence Shell Electron-Pair Repulsion
## VSEPR ("Ves-per")

**Unshared Pairs Repel – maximize distance between pairs**
**Creates Molecular Geometry**




**Extension of Lewis Dot Structures**

**Beyond CEM 101 Level**



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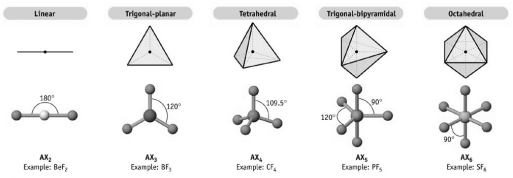
## Valence Shell Electron Pair Repulsion (VSEPR)

**Central Atom Bonding Determines Molecular Shape**

**Number of electron bonding groups:**

**2 3 4 5 6**





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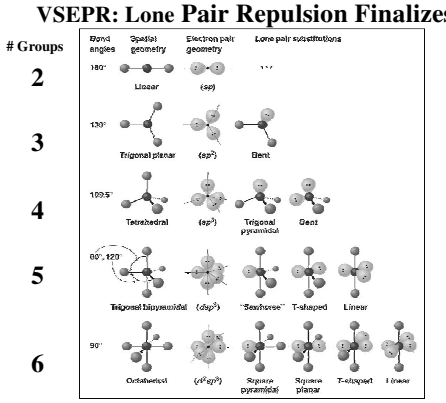
## VSEPR: Lone Pair Repulsion Finalizes Shape



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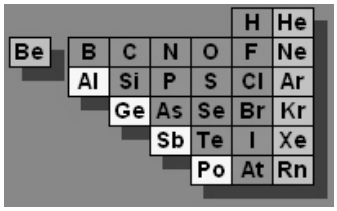
## Valence Shell Electron-Pair Repulsion

**Uses unshared electrons to predict molecular shape**




**Primarily used with non-metal central atoms ('cause they have more electrons)**



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## Drawing Lewis Structures

**$SO_3$**

**Major pollutant in power plant emissions**

**$SO_3 + H_2O \rightarrow H_2SO_4$**

**Electronegativity:**
**S = 2.5**
**O = 3.5**



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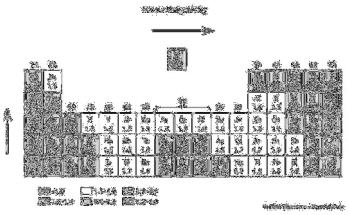
## Step One: Determine Least Electronegative Atom



Least Polar Atom
Becomes Central
In Lewis Structure

H never Central

Electronegativity Differences

Δ ≤ 0.4 → non-polar covalent
Δ > 0.4 - 1.9 → polar covalent
Δ> 1.9 → ionic

Δ = difference in electronegativity of the bonded atoms

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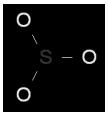
## Step Two: Calculate Valence Electrons for Each Atom



Sum the valence electrons of all the atoms in the unit
Add one electron for each net negative charge
Subtract one electron for each net positive charge

For $SO_3$:
S = 6 electrons
O = (3 x 6) = 18 electrons
Total = 24 electrons

Divide by 2 to get number of electron pairs
24 electrons / 2 = 12 electron pairs

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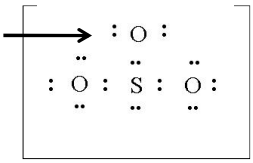
## Step Three: Distribute Electrons around Central Atom

One pair between the central atom and each ligand atom
Central atom filled to octet
Additional pairs on each outer atom (except hydrogen)

For $SO_3$ → Drawing to total of 12 pairs

Not Octet →



Not all atoms have octet

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**Step Four: Use "Formal Charge" to Resolve Octets**
**Need Formal Charge to be 0 on all atoms**
**or the charge on ionic species**

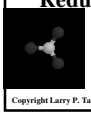
**Formal Charge = # valence $e^-$ – ( # unshared $e^-$ + 0.5 * bonding $e^-$ )**

**For Sulfur (the central atom)**

**F = 6 (group 6 atom) – (2 +3 (6/2) )**
**F = 6 – 5 = +1**

**In terms of "molecular Psychology"**
**Sulfur not "happy" with a full +1 charge**

**Reduce formal charge with multiple bond formation**





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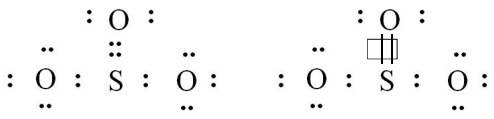
**Step Five: Add multiple bond to complete octet**





**Step Six: Recalculate Formal Charges**

**Sulfur: 6 – (0 +4) = +2**
**Oxygen in bottom row: 6 – (6 + 1) = -1**
**Oxygen at top: 6 – (4+2) =0**
**Formal Charges balance: 2 x (-1) electrically balances +2**



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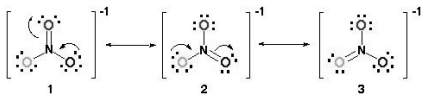
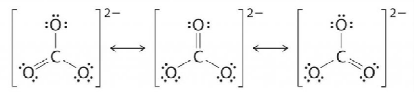
## Resonance

**Concept used to explain observed bond lengths**
**Describes molecules where bonding cannot be expressed with a single Lewis Structure**
**Electrons assumed to be delocalized throughout the system**
**Result is defined as a "resonance hybrid" of several forms**
**Individual resonance structures do not exist**







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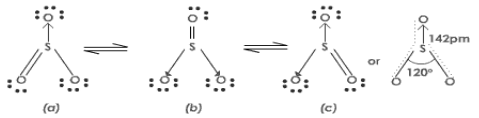
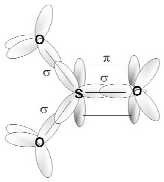
## $SO_3$: Resonance Stabilized




**STRUCTURAL CALCULATIONS**

| | |
|---|---|
| Molecular Formula: | $SO_3$ |
| Systematic Name: | Sulfur Trioxide |
| Central Atom: | S (Sulfur) |
| Valence Electrons: | 24 |
| Total Electrons: | 40 |
| Bonded Pairs: | 3 |
| Lone Pairs: | 0 |
| Electron Pairs: | 3 |
| Single Bonds: | 2 |
| Double Bonds: | 1 |
| Triple Bonds: | 0 |
| XAX Bond Angle: | 120° |
| EP Arrangement: | Trigonal Planar |
| Molecular Geometry: | Trigonal Planar |
| VSEPR Notation: | $AX_3$ |

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## Bond Order

**Covalent Bonds: Number of electron pairs in the bond**

**C ≡ C  C = C  C — C**

**Bond Order:  3  2  1**

**Resonance Bonds: # Electron Pairs / Total Bonds of same type**

**O = N — O ⟷ O — N = O**

**Bond Order = $\frac{\text{3 e}^- \text{ Resonance Pairs}}{\text{2 N— O Bonds}}$ = 1.5**

**> Bond Order: Shorter and stronger the bonding between atoms**

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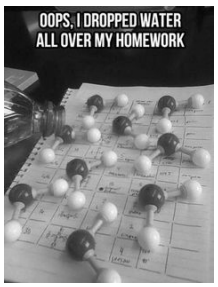





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