

- Electronegativity
  - Electronegativity** is a measure of how much atoms want electrons.
    - Electronegativity differences between two atoms helps tells you which type of bond they participate in.
      - Nonpolar bond has electronegativity differences less than 0.5.
      - Polar, covalent bonds have electronegativity differences between 0.5 and 2.
      - Ionic bonds generally have electronegativity differences greater than 2.
    - Trend:

# INCREASING ELECTRONEGATIVITY

1 <b>H</b> Hydrogen 1.00794																	2 <b>He</b> Helium 4.003				
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012182															5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.0107	7 <b>N</b> Nitrogen 14.0064	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.9984032	10 <b>Ne</b> Neon 20.1797
11 <b>Na</b> Sodium 22.989770	12 <b>Mg</b> Magnesium 24.3050															13 <b>Al</b> Aluminum 26.981538	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973761	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.4527	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.955910	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938049	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933200	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.61	33 <b>As</b> Arsenic 74.92160	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.80				
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.90550	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29				
55 <b>Cs</b> Cesium 132.90545	56 <b>Ba</b> Barium 137.327	57 <b>La</b> Lanthanum 138.9055	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.217	78 <b>Pt</b> Platinum 195.078	79 <b>Au</b> Gold 196.96655	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98038	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)				
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89 <b>Ac</b> Actinium (227)	104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (263)	107 <b>Bh</b> Bohrium (264)	108 <b>Hs</b> Hassium (265)	109 <b>Mt</b> Meitnerium (266)	110 <b>Ds</b> Darmstadtium (269)	111 <b>Rg</b> Roentgenium (272)	112 <b>Cn</b> Copernicium (277)	113 <b>Nh</b> Nihonium (284)	114 <b>Fl</b> Flerovium (289)								

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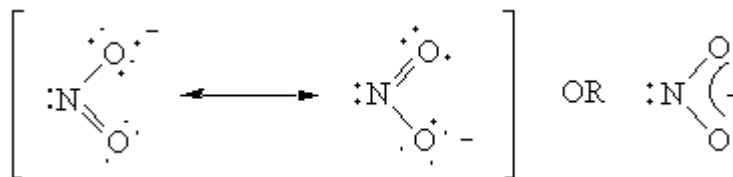
- Lewis structures special notes
  - Elements not part of the transition metal block and are in the 3<sup>rd</sup> period and below can have expanded octets.
  - Boron is electron deficient, only needed 6 electrons to fill its shell.
  - When adding up the valence electrons in a molecule, if you get an odd number, then it is a radical.
- Formal charge
  - The **formal charge** is the charge of an atom in a molecule. By adding all the formal charges of all the atoms in a molecule, you can determine if the overall molecule is positive, negative, or neutral.
  - Equation:

$$\begin{aligned}
 VE &= \text{valence electrons} \\
 NE &= \text{nonbonding electrons} \\
 BE &= \text{bonding electrons} \\
 \text{Formal Charge} &= VE - NE - \frac{BE}{2}
 \end{aligned}$$

- Resonance structures
  - A **resonance structure** is another way to depict the same molecule. Only electrons can move around, not atoms!
  - How to determine importance of resonance structure to the overall structure (most important to least important factors):
    - 1) All atoms have full octets
    - 2) Minimal separation of charge
    - 3) More electronegative atom should have the negative charge whereas the more electropositive atom should have the positive charge.
  - In reality, all resonance structures for the same molecule exist **at the same time, all the time**.
  - Most important resonance contributor best describes the shape of the molecule whereas the second most important resonance contributor best describes the reactivity of the molecule.



- Bond length
  - Bond length** describes the distance of a bond between two atoms.
  - How do rank bond lengths:
    - Bond length follows the atomic radius trend. Larger atoms that bond together will have larger bond lengths for this reason. (H-Br > H-F)
    - single bond > double bond > triple bond
    - higher % s character ( $sp > sp^2 > sp^3$ ) of the atoms participating in the bond, the shorter the bond
  - NOTE: watch for resonance!



- This is  $\text{NO}_2^-$ , or nitrite. When looking at the N-O bond lengths, one might be tempted in saying that one N-O bond is strictly a double bond while the other is a single bond.. However, this is not true! Note that the molecule can resonate! Because of this, the N-O bond length is actually less than 2, it is around 1.5.
    - When given a bond length problem, look for resonance because that can affect the way you answer the question.**
- Bond strength
  - Bond strength** indicates how much energy is needed to break a bond into two equal atoms.
  - General rule: the shorter the bond is, the stronger the bond is
  - How to rank bond strength:
    - triple bond > double bond > single bond
    - Higher % s character ( $sp > sp^2 > sp^3$ ) of the atoms participating in the bond, the stronger the bond strength. This is because the atoms participating in the bonds are in lower energy orbitals and are more tightly bound by the nucleus.
  - NOTE: watch for resonance (just like bond length)!
- Molecular geometry
  - Determining hybridization:
    - 1) count every single, double, or triple bond around a given atom as “1”
    - 2) count every lone pair around the same atom as “1”
    - 3) add up the two counts and then use the table to determine hybridization

Count	Hybridization
2	$sp$
3	$sp^2$
4	$sp^3$
5	$sp^3d$
6	$sp^3d^2$

- NOTE: watch for resonance! The resonance structure with the smallest observed hybridization best describes the overall hybridization!
- $sp^3 = \sim 109^\circ$  bond angles and a tetrahedral arrangement
    - 4 bond sand 0 lone pairs = tetrahedral
    - 3 bonds and 1 lone pair = trigonal pyramidal
    - 2 bonds and 2 lone pairs = bent
    - 1 bond and 3 lone pairs = linear
  - $sp^2 = \sim 120^\circ$  bond angles and trigonal planar arrangement



- 3 bonds and 0 lone pairs = trigonal planar
  - 2 bonds and 1 lone pair = bent
  - 1 bond and 2 lone pairs = linear
- $sp$  =  $\sim 180^\circ$  bond angles and linear arrangement
- **lone pair electrons** take up extra space and crunches the bond angles. The more lone pairs that exist around an atom, the smaller the bond angles are.
- Intermolecular forces
  - **Intermolecular forces** are forces that occur between neighboring particles. They have big effects on physical properties.
  - In terms of strength: Ion-dipole > hydrogen-bonding > dipole-dipole > van-der-waals
  - **Ion-dipole** is an interaction between an ion and an oppositely charged dipole.
  - **Hydrogen bond** is the interaction between a lone pair on fluorine, oxygen, or nitrogen and a hydrogen on another molecule that is directly bound to fluorine, oxygen, or nitrogen.
    - NOTE: hydrogen bonding can occur between atoms within the same molecule. Intramolecular H-bonds prevent intermolecular H-bonds from forming and thus weakens its effect on physical properties.
  - **Dipole-dipole** occurs from polar covalent bonds.
    - NOTE: dipoles within the same molecule can cancel each other out if the dipoles are in the opposite directions and are of the same magnitude. Factor in the NET molecule dipole.
  - **Van-der-waals** occurs between all atoms. It is the brief attraction between neighboring molecules due to the random movement of electrons.
    - The larger the molecular weight, the stronger the VDW forces.
    - The bigger the molecule is (more surface area), the stronger the VDW forces.
    - The more “branched” the molecule is, the weaker the VDW forces.
- Melting points, boiling points, and solubility
  - Boiling point ranking:
    - 1) The stronger the IMFs, the higher the boiling point
      - Note that for hydrogen bonding, oxygen > nitrogen (you will probably never see a fluorine molecule).
    - 2) The larger the surface area of the molecule, the higher the BP
    - 3) The more polarizable the atom is, the higher the BP
      - **Polarizability** is described as the ease of distortion of the electron cloud of a molecule by an electric field. Polarizability increases down the column of the periodic table. ( $I > Br > Cl$ )
      - NOTE:  $HF > HI > HBr > HCl$  for boiling point (note that HF can do hydrogen bonding whereas the other 3 acids cannot)
  - Melting point ranking:
    - 1) The stronger the IMFs, the higher the melting point
    - 2) The more branched the molecule is, the higher the melting point
  - Solubility ranking:
    - 1) similar IMFs between solvent and solute
    - 2) the larger the surface area of the solute is, the less dissolving there is