Bonding

I. Energy Changes in Bonding
- A. Chemical Bond - result of the attraction of electrons between two atomic nuclei
  - 1. Formation of a chemical bond releases energy (exothermic)
    - a. more stable configuration
      - 1. The more energy given off in a bonding reaction, the more stable the resulting molecule is.
  - 2. Breaking of a chemical bond absorbs energy (endothermic)
  - 3. Equal amounts of energy needed to break and form the same bonds

II. Types of Bonds - determined by electronegativity differences (Table S)
- A. Ionic Bonds - transfer of 1 or more electrons from metals to nonmetals
  - 1. Metals - + charge (lose electrons) are called cations
  - 2. Nonmetals - - charge (gain electrons) are called anions
  - 3. electronegativity difference between the two substances must be greater than 1.7
    - a. exceptions to this are metal hydrides ex. NaH
    - b. all metal hydrides are ionic in nature
- B. Covalent Bonds - sharing of electrons
  - 1. electronegativity difference is less than 1.7
  - 2. Types of covalent bonds
    - a. Nonpolar - equal sharing of electrons with no electronegativity difference
      - 1. ex. Cl_2 , O_2
    - b. Polar - (dipole) unequal sharing of electrons - has electronegativity difference
      - 1. ex. HCl
- C. Metallic Bonds - consist of positive ions that are located at crystal lattice sites and are immersed in a sea of mobile electrons
  - 1. caused by low number of valence electrons and low ionization energies (easy to move)
    - a. good conductors of electricity and heat
    - b. great strength
    - c. malleability and ductility
    - d. luster

III. Types of Substances
- A. Molecular Substances - discrete particles formed by covalently bonded atoms
  - 1. Molecular Solids
    - a. soft
    - b. good electrical insulators
    - c. poor heat conductors
    - d. low melting & boiling points
  - 2. Chemical formula – indicates the relative numbers of atoms of each kind in a chemical compound by using atomic symbols and numberical subscripts.
  - 3. Molecular formula – shows the types and numbers of atoms combined in a single molecule of a molecular compound.
  - 4. Bond length – the average distance between two bonded atoms.
    - a. Single bonds between 2 atoms have greatest length
    - b. Double and triple bonds get progressively shorter.
  - 5. Bond energy – amount of energy required to break a chemical bond and form neutral isolated atoms.
  - 6. ***Formation of Covalent Bonds***

a. ***Covalent bond - forms from overlapping of an orbital with the orbital of another atom***

1. ***Sigma bond (s)***

a. ***overlapping of 2 s orbitals (s $_s$)***

b. ***overlapping of an s orbital and a p orbital (s $_{sp}$)***

c. ***overlapping of 2 p orbitals end to end (s $_p$)***

2. ***Pi bond (p)***

a. ***overlapping of 2 p orbitals sideways***

1. ***distortion of orbitals occurs***

7. ***Types of Bonds***

a. ***Coordinate Covalent - two shared electrons come from one element***

1. ***forms polyatomic ions (charged)***

a. ***ex. NH_4^+ , H_3O^+***

8. ***Resonance Structures - equivalent alternative structures for a molecule or polyatomic ion which lead to average bond lengths***

a. ***Compounds cannot always be represented by a single structural formula***

b. ***Network Solids - atoms linked in a network that extends throughout the substance***

a. ***hard***

b. ***poor conductors of electricity***

c. ***high melting points***

1. ***ex. C (diamond), SiC, SiO_2 (quartz)***

B. Ionic Solids & Substances

1. Formula Unit – simplest collection of atoms from which an ionic compound's formula can be established.
2. Very high bond energy (called lattice energy)
3. high melting & boiling points
4. do not conduct electricity
5. ions form a crystal lattice (NaCl, MgO)
6. Melted (liquid) or dissolved ionic solids ions move freely
7. allows conduction of electricity

C. Metallic Substances - consist of positive ions that are located at crystal lattice sites and are immersed in a sea of mobile electrons

1. caused by low number of valence electrons and low ionization energies (easy to move)
   a. good conductors of electricity and heat
   b. great strength
   c. malleability and ductility
   d. luster

D. Polyatomic Ions - two or more covalently bonded atoms with a charge that behave like a monoatomic ion (Table E in Reference tables)

1. forms an ionic bond with metals.

IV. Lewis Dot Structures - Dot Diagrams for Ionic Substances, Molecules and Polyatomic Ions

A. Octet rule – Chemical compounds tend to form so that each atom, by gaining, losing, or sharing electrons has an octet of electrons in its highest occupied energy level.

1. exceptions – Boron

B. Structural formula – indicates the kind, number, arrangement, and bonds, but not the unshared pairs of electrons of the atoms in a molecule

C. Ionic Substances

1. Write the balanced formula for the substance.
2. Put brackets around all elements
3. Put no dots around the + ion(s) and write the charge

4. Put 8 dots around the – ion(s) and write the charge

D. Molecular substances
1. Write the balanced formula for the substance
2. Write the electron dot structures of all atoms.
3. Draw a line from the unpaired electrons of one element to the unpaired electrons of a different element.
4. Redraw the structure by placing the atoms which share electrons next to each other – be sure that each atom has 8 electrons around them except for Hydrogen (2)

E. ***Poly Atomic ions and compounds***
1. ***Write down the symbols of the atoms in the molecule in a way that shows how the atoms are joined together***
   a. ***elements in formula are usually written in order atoms are connected***
   b. ***the central atom is usually a nonmetal other than hydrogen or oxygen***
      a. ***Make a trial drawing representing shared electrons and stable octets around each atom (except H which has 2)***

F. ***Hybridization- Molecular Geometry***
1. ***Molecular Shapes - VSEPR Model (valence shell electron pair repulsion)***
   a. ***each pair of electrons surrounding the central atom is considered to repel all other electron pairs***
      1. ***all electron pairs move as far from other electron pairs as possible***
      2. ***lone pair electrons take up the same space as a bond.***
2. ***the rearrangement of electrons within the valence orbitals of atoms during a chemical reaction***
   a. ***s electrons in the orbitals are "promoted" to empty p orbitals***
      1. ***sp hybridization - group IIA elements***
         a. ***one s electron is promoted to the p orbital allowing each electron to pair with another electron***
      2. ***sp^2 hybridization - group IIIA elements***
         a. ***one s electron is promoted to the next p orbital, allowing all three valence electrons to pair with another electron***
      3. ***sp^3 hybridization - group IVA elements***
         a. ***one s electron is promoted to the next p orbital, allowing all four valence electrons to pair with another electron***
   b. ***Directional Nature of Covalent bonds - depending on the shape of the molecule, a Nonpolar molecule may form from several polar bonds***
      1. ***ex. O=C=O is nonpolar***
      2. ***ex H_2O is polar***

3. Group IV, V, VI, VII shapes
   a. Tetrahedral Shape (4 shared pairs)
      1. ***electrons evenly space produce a 109.5° angle (ex. Methane CH_4)***
   b. Pyramidal Shape (3 shared pairs)
      1. ***angle is less than 109.5° due to repulsive effect of unshared electrons***
         a. ***produces an angle of 107° (ex. NH_3)***
   c. Bent Shape (2 shared pairs)
      1. ***angle is even less than the 109.5° angle due to the repulsive effect of 2 pairs of unshared pairs of electrons***
         a. ***produces an angle of 105° (ex. H_2O)***
   d. Linear (1 shared pair)

1. ***angle is equal to 180°***

V. Intermolecular Attractions - molecules are attracted to each other because of charged ends of the molecules.

A. Dipoles -caused by electronegativity differences in formation of molecules

1. effects the boiling points and melting points of compounds
2. Dipoles - caused by polar molecules attracting one another
3. Hydrogen bonding - special form of dipole attraction which involves hydrogen
    a. hydrogen usually acts as a bare proton (usually with smaller, highly electronegative electrons
        1. stronger bonding causes higher boiling point and lower vapor pressure (ex. H_2O)

B. Van der Waals forces - weak intermolecular forces formed from nonpolar molecules

1. causes substances to have a low boiling point and melting point
    a. allows nonpolar substances to form liquids and solids under high pressure and low temperature

C. Molecule Ion Attraction - polar molecules interact with ionic compounds and form a solution

1. Ionic substances are separated to the opposite polar ends of the molecules