1 VSEPR/IMFs

1.1 Types of Bonding

Chemical components are formed by the joining of two or more atoms. When atoms bond, their valence electrons are redistributed in ways that make the atoms more stable. The way the electrons are redistributed depends on the type of bond formed.

A chemical bond is a mutual attraction between the nuclei and valence electrons of different atoms that binds atoms together.

Ionic bonds are the result of the electrical attraction between positive and negative ions.

The ions are formed because atoms completely give up their electrons to other atoms.

Ionic Bonds

- These bonds usually occur between a metal and a nonmetal, creating an ionic compound, also known as a salt.
- Both atoms end up with an octet of electrons in their valence shell.
- Salts are neutral because they have an equal positive and negative charge.
- Metals lose electrons and nonmetals gain electrons in an ionic compound.

Covalent Compounds

- These bonds are the result of the sharing of electron pairs between two atoms.
- In a covalent bond, the electrons are "owned" by the two bonded electrons.

Covalent bonds usually occur between two nonmetals and results in individual molecules.

Metallic Bonding

- In pure metals or alloys, there are usually vacant valence orbitals. The vacant orbitals overlap from one atom to another, allowing the outermost electrons to roam freely throughout the entire metal.
- These are called delocalized electrons. These mobile electrons, a "sea of electrons", move throughout the entire metal.
- Metallic bonds are the result of the attraction between metal nuclei and the surrounding sea of electrons.

Exercise - What type of bonding is present in carbon dioxide? (covalent)

1.2 Bonding

A chemical bond is an attractive force between atoms or ions that binds them together as a unit. Bonds form in order to decrease potential energy and increase stability.

What is Chemical Bonding?

- A chemical bond is formed when electrons are shared or given between two or more atoms.
- The electrons involved are only the outermost electrons - the valence electrons.
- Chemical Bond - a link between atoms that holds them together.

Keeping Track of Electrons:

- The electrons responsible for the chemical properties of atoms are those in the outer energy level.
- Valence electrons - The s and p electrons that are in the highest energy level.

- Core (or shielding) electrons - those in the energy levels below.

Remember atoms in the same column have the same outer electron configuration and have the same number of valence electrons.

In the s block, the number of valence electrons is the group number, in the d block the number of valence electrons varies and isn't always predictable, and in the p block the number of valence electrons is the group number minus 10.

Exercise - How many valence electrons does phosphorus have? (5)

Atoms typically bond to form an octet in their valence level. All atoms want this stability. This is also called "noble gas configuration".

When an atom gains or loses electrons, it is an ion. Loss of electrons is a cation and is positively charged. Gain of electrons is an anion and is negatively charged.

Intramolecular bonds hold atoms to atoms - they are your ionic, covalent, and metallic bonds.

Intermolecular Bonds hold two or more molecules/ions together. They are your hydrogen, dipole-dipole, ion-dipole, and london dispersion forces.

Ionic Bond

- An ionic bond is formed when electrons are transferred from one atom to another. This creates positive and negative ions.
- When one or more electrons is transferred, you get both a positive and negative ion.
- Since they have opposite charges, they are attracted to one another. This is called an "electrostatic attraction".
- Ionic bonds typically form with a metal and a nonmetal.
- Ionic substances are sometimes caleld salts.
- Overall, salts are neutral. They have equal amounts of positive and negative charge.

What are ionic compounds?

- Because of their valence electron structure, metals lose their electrons, and nonmetals gain electrons.
- This is why metal ions have a positive charge and nonmetal ions have a negative charge.

Formula Unit

- A formula that tells the ratio of ions in an ionic compound.
- The smallest part of an ionic compound that still has the composition of the compound.

Lewis Dot notation can be use to visualize ionic compounds and how they form.

Properties of Ionic Compounds

- High melting points/boiling points - it takes a lot of energy to break strong bonds.
- Hard, brittle solids
- Many are soluble inw ater
- When dissolved, free ions float and conduct electricity
- Form crystalline solids

Do they conduct?

- Conducting electricity is allowing charges to move.
- In a solid, the ions are locked in place - ionic solids are insulators.
- When melted, the ions can move around.
- Melted ionic compounds conduct.
- Dissolved in water they can conduct.

In order for electrons to be transferred, one element must be much more electronegative than the other. They must have an EN difference of more than 1.7. In general, most combinations of metal+nonmetal will have this great ΔEN.

Covalent bonds are a bond that results from the sharing of electrons. They are made of molecules instead of crystal lattice and usually occur between two nonmetals. When two atoms do not have a big ΔEN, they will share electrons. There are varying degrees of how electrons can be shared.

- Shared equally: nonpolar covalent bond. The EN values are almost equal, a difference less than 0.5
- Shared unequally: polar covalent bond. The EN values are not equal, but not different enough to form an ionic bond.

In nonpolar covalent bonds, electrons are shared equally, the molecule overall is neutral.

In polar covalent bonds, electrons are not shared equally. The more electronegative atom attracts the electrons more, forming a partially negative region of the atom. The less electronegative atom becomes partially positive.

Properties of Covalent Bonds

- No ions, no charges, do not conduct electricity.
- Weak attraction between molecules.
- Usually liquids or gases at room temperature.
- If solid, have low melting points.
- Amorphous Solid - do not have a regular/repeating pattern.

Most bonds are a blend of ionic and covalent characteristics. Difference in electronegativity determines bond type.

Metallic bonds occur between metal atoms. Bonding due to a "sea of electrons" - electrons that are not bound to one specific atom, they are able to move around the substance from atom to atom. Accounts for properties of metals and metal alloys.

Metals are

- Malleable
- Ductile
- Good at conducting heat and electricity

Properties are due to the free-floating electrons.

Exercise - What type of bond is CH_4 (nonpolar covalent)

Lewis Structures:

- Lewis structures can be drawn for both ionically and covalently bonded compounds.
- Just keep in mind ionically bonded salts will contain ions.
- Covalently bonded molecules will show shared electrons.

Types of Covalent Bonds:

- Single Bond - one pair of electrons is shared; represented by a single line drawn between two atoms.
- Double Bond - two pairs of electrons shared; represented by two lines drawn connecting the two atoms.
- Triple Bond - three pairs of electrons shared; represented by three lines drawn connecting the two atoms.

Multiple Bonds: usually formed by C, N, O, P, S

Triple bonds are stronger than double bonds and double bonds are stronger than single bonds. It takes more energy to break a double bond than a single bond, and more energy to break a triple bond than a double or single bond.

Multiple bonds increase the electron density between two nuclei. As the electron density increases, the repulsion between the two nuclei decreases. An increase in electron density also increases the attraction each nucleus has for the additional bonding electron pairs. The nuclei move closer together and the bond length is shorter for a double bond than a single bond.

Predicting the Arrangement of Atoms within a molecule:

- H is always a terminal atom. H is ALWAYS connected to only one other atom.
- The element with the lowest electronegativity is the central atom in the molecule. Put other atoms around the central atom.
- Find the total # of valence electrons by adding up group #'s of the elements. For ions add electrons for negative charges and subtract electrons for positive charges. Divide by two to get the number of electron pairs available to go around.
- Use a pair of electrons to connect each terminal atom to the central atom.

Usually central atoms will have 4 things around them, so spread atoms at 90 degree angles.

- Place lone pairs about teach terminal atom to satisfy the octet rule.
- Left over pairs are assigned to the central atom. If the central atom is from the 3rd of higher period, it can accommodate more than four electrons pairs.
- If the central atom is not yet surrounded by four electron pairs, convert one or more terminal atom lone pairs to pi bonds pairs. Not all elements form pi bonds! Only C, N, O, P, and S.

Remember, only C, N, O, P, S are able to form multiple bonds.

Exceptions to the octet Rule:

- Electron Deficient: less than 8 electrons
  - Hydrogen: 2 in outer energy level
  - Boron: 6 in outer energy level
  - Beryllium: 4 in outer energy level
- Exceed Octet: more than 8
  - anything in 3rd period or heavier
  - because d-orbitals are available and add extras to the middle atom.

Often times there is more than one possible way for atoms to bond together in a given molecule.

VSEPR:

- Valence Shell Electron Pair Repulsion
- We've already discussed this - areas of electrons around a central atom tend to spread out to reduce electrostatic repulsion
- Can be used to predict 3-D shape of molecules.

Areas of Electron Density:

Bonded electrons or unbonded electrons (lone pairs). These areas spread as far apart from each other as possible.

Molecules are nonpolar if they have only one kind of terminal atom and no lone electron pairs on the center atom. Molecules are polar if they have more than one kind of terminal atom or at least one lone electron pair on the central atom.

Hybridization is the mixing of different types of atomic orbitals to produce a set of equivalent hybrid orbitals. For assigning hybridization, we tell what type of orbitals are mixed.

We will use the following key now for describing shapes: "A" represents the central atom, "X" represents the atoms attached to the central atom, and "E" represents a lone pair of electrons on the central atom.

- 2 bonding regions, 0 lone pairs - AX_2 - linear - usually nonpolar - hybridization: sp - bond angle: 180°

- 3 bonding regions, 0 lone pairs - AX_3 - trigonal planar - usually nonpolar - hybridization: sp^2 - bond angle: $120°$
- 2 bonding regions, 1 lone pair - AX_2E - bent - always polar - hybridization: sp^2 - bond angle: $< 120°$
- 4 bonding regions, 0 lone pairs - AX_4 - tetrahedral - usually nonpolar - hybridization: sp^3 - bond angle: $109.5°$
- 3 bonding regions, 1 lone pair - AX_3E - trigonal pyramidal - always polar - hybridization: sp^3 - bond angle: $107°$
- 2 bonding regions, 2 lone pairs - AX_2E_2 - bent - polar - hybridization: sp^3 - bond angle: $104.5°$
- 5 bonding regions, 0 lone pairs - AX_5 - trigonal bipyramidal - usually nonpolar - hybridization: under debate - bond angle: $90°, 120°, 180°$
- 4 bonding regions, 1 lone pair - AX_4E - seesaw - polar - hybridization: under debate - bond angles: $< 90°, < 120°, < 180°$
- 3 bonding regions, 2 lone pairs - AX_3E_2 - T-shaped - polar - hybridization: under debate - bond angles: $< 90°$
- 2 bonding regions, 3 lone pairs - AX_2E_3 - linear - polar - hybridization: under debate - bond angle: $180°$
- 6 bonding regions, 0 lone pairs - AX_6 - octahedral - usually nonpolar - hybridization: under debate - bond angles: $90°, 180°$
- 5 bonding regions, 1 lone pair - AX_5E - square pyramidal - polar - hybridization: under debate - bond angles: $< 90°, < 180°$
- 4 bonding regions, 2 lone pairs - AX_4E_2 - square planar - polar - hybridization: under debate - bond angles: $90°$
- 3 bonding reginos, 3 lone pairs - AX_3E_3 - T-shaped - polar - hybridization: under debate - bond angles: $< 90°$

Hybridization: The mixing of different types of atomic orbitals to produce a set of equivalent hybrid orbitals.

Polarity - bonds can be polar while the molecule isn't and vice versa.

Molecular Polarity - if a central atom has no lone pairs of electrons and all surrounding bonds are identical, then the molecule is nonpolar. Even though a molecule might have polar bonds within it, if those polar bonds cancel each other out, the molecule is nonpolar.

Molecules that have lone pairs of electrons on the central atom and.or different types of terminal atoms attached to the central atom are considered polar molecules. The charge is unevenly distributed throughout the molecule.

Exercise - Is O_3 polar or nonpolar. (polar)

There are many types of bonds that hold that hold molecules and molecules or molecules and ions together. These forces are incredibly important.

London Dispersion Forces

- These are the forces that exist among non-ionic and non-polar substances.
- They exist among noble gases and nonpolar molecules.
- These forces are weak.

They are caused by an instantaneous dipole formation in which electron cloud becomes asymmetrical, and the molecules are slightly attractive to each other. This is the weakest intra- and intermolecular forces.

When you are comparing two substances that both have dispersion forces:

- The substance with more electrons has stronger dispersion forces since its electron cloud is larger and more polarizable.

Heavy noble gases have stronger dispersion forces than lighter noble gases.

Dipole-dipole forces

- These forces exist between molecules that have permanent dipole moments.
- Look for molecules with lone electron pairs on the central atom or different types of terminal atoms.
- These molecules have an uneven distribution of charge and therefore have attraction to each other.

Dipole-dipole forces are stronger than dispersion forces since the polarity in these molecules is permanent.

Hydrogen bonding is a special subset of dipole-dipole forces that exist only in H-N, H-O, and H-F.

This results in a partially positive pole and partially negative pole.

- When two or more water molecules are near each other, the weak positive hydrogen atom of one molecule will be attracted to the weak negative oxygen atom of the other molecule.
- This attraction between molecules is called hydrogen bonding.
- After many hydrogen bonds are formed, you have a weak force holding all the water molecules to each other.
- Hydrogen bonding is the reason water freezes into ice crystals of a certain repeating shape.
- Remember that hydrogen bonding can occur between any molecules that contain O-H, N-H, F-H bonds.

Hydrogen bonds have a high boiling point. It takes a large amount of energy to boil water into vapor because of the bonds holding the molecules together. The bonds must be broken in order for the liquid to change to a gas.

Hydrogen bonds also have high surface tension.

Water molecules are attracted to the glass because glass molecules are also polar, but not attracted to nonpolar plastic, so there is no meniscus in a plastic graduated cylinder.

Water can be drawn up into a thing glass tube with no effort because of the attraction between the water and glass molecules.

Surface tension can be decreased by adding a surfactant - this type of substance interferes with hydrogen bonding.

The Last IMF - ion-dipole forces.

- Attraction that helps ionic compounds dissolve in a polar substance.
- Think of salt water.

Exercise - What IMF is present in CI_4? (LDFs)