

Lecture 1 — Bonding

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- Covalent Bonds
 - Bonds created by the structuring of valence electrons of atoms
- Where are Covalent Bonds Found?
 - Electronic semiconductor systems (Si, Ge, SiC, GaN, diamond)
 - 2-D systems within the sheet (*i.e.* graphene)
 - Wherever we find $3p^2$ and $3p^3$ bonds
- Metallic Bonding
 - Non-directional collective sharing of electrons
 - Under an applied force, ions can move with respect to each other, especially when defects are present, hence metals are ductile
 - Free valence electrons in the electron gas respond readily to applied electric fields and drift along the force of the field causing high electrical conductivity
- Where are Metallic Bonds Found?
 - Semiconductor system interconnect
 - Metallization
 - Bonding Technologies
- Ionic Bonding
 - Sodium Chloride (NaCl) is an example
 - * Sodium donates its single valence electron to complete chlorine's outer shell, causing it to be attracted via Coulombic forces

- The electrostatic force of attraction between positive and negative ions that holds them together is called an ionic bond
- Ionic bonds are also called electrovalent bonds
- Oftentimes, a crystalline structure is formed
- Bonds are held at a potential energy minima
- Determining Ionicity
 - Electronegativity was introduced by Linus Pauling; Fluorine is assigned an electronegativity of 3.98, and other elements are scaled relative to that value
 - Across a period (left to right), electronegativity increases due to increasing nuclear charge and decreasing atomic radius
 - Down a group (top to bottom), electronegativity decreases due to increasing atomic radius and greater electron shielding
 - Electronegativity difference determines bonds:
 - * Difference of 0-.39: Non-Polar Covalent Bond
 - * Difference of .4-1.69: Polar Covalent Bond
 - * Difference of 1.7 or more: Ionic Bond
- Where are Ionic Bonds Found?
 - Solid-state ionic conductors are essential components of lithium-ion batteries
 - Proton exchange membrane fuel cells (PEMFCs)
 - Supercapacitors, a novel class of electrochemical energy storage devices
 - Solid oxide fuel cells, devices that produce electricity from oxidizing fuel
- Covalent versus Ionic Bonds: Covalent refers to a shared electron, while ionic refers to electron transfer
- Secondary Bonding and Van der Waals Bonds
 - Covalent, metallic, and ionic are primary bonds
 - Between all types of atoms and molecules there exists a weak attraction — the Van der Waals (London) Force
 - In many molecules, the concentrations of $-$ and $+$ charges do not coincide
 - * This creates an electric dipole moment
- Where are Van der Waals Bonds Found?
 - 2-D Electronic Systems (between layers)