Intermolecular Forces – Review
Intermolecular forces (IMF)

- Intermolecular forces are interactions **between** two or more molecules or atoms.
  - IMF is based upon polarity and Coulomb's Law
  - The 5 intermolecular forces, in order of increasing strength (weakest to strongest) are:
    - London dispersion forces (LDF) < dipole-induced dipole forces < dipole forces < hydrogen bonding < ionic bonding
  - The **stronger** the IMF, the **greater** the interaction between two particles, resulting in a **higher** mp and bp since it would require **more** energy (in the form of heat or compression) to disrupt the intermolecular forces present between them and permit a phase change.
London dispersion forces

- London dispersion forces are present between ALL substances (polar/non-polar).
- The only IMF that **non-polar** particles exhibit are LDF
- As two particles get closer together, LDF interactions **increase** in strength
  - This is because as you decrease the distance of separation (r) between two particles, Coulombic repulsion of the two particles' electron cloud will force electron density to redistribute, inducing a temporary (or instantaneous) dipole in order to maximize attraction and minimize repulsion.
- As you increase in molecular size (MW), the strength of LDF **increases**
  - This is because as you increase in molecular weight, the molecule becomes larger. The larger the molecule, the larger the electron cloud, and therefore the greater the dispersion forces.

---

[Diagram of I₂ bond with London dispersion forces]
**Dipole-induced dipole**

- Recall that non-polar substances do **NOT** have a dipole moment.
- When a polar particle approaches a non-polar particle, the polar substance induces a temporary dipole on the non-polar particle that wasn't there originally.
- This temporary dipole occurs in order to **maximize** Coulombic attraction and **minimize** Coulombic repulsion.

[Diagram showing dipole-induced dipole interaction]
Dipole forces

- Recall that polar substances **have** dipole moments
- Dipole forces are present between **ALL** polar substances
- The **negative** dipole on a polar molecule is Coulombically attracted to a positive dipole on another polar molecule
- The **positive** dipole on a polar molecule is Coulombically attracted to a negative dipole on another polar molecule

\[
\begin{align*}
\text{H} & \rightarrow \delta^+ \\
\text{Cl} & \rightarrow \delta^-
\end{align*}
\]
Hydrogen bonding

- Hydrogen bonding is present when a polar substance has a H that is bonded to a highly electronegative atom (i.e. N, O, or F)
- H-bonding is extremely strong; so strong that it can stably maintain the structure of large macromolecules, such as proteins and nucleic acids
Ionic bonding

• Recall, ions are **polar** because they have a permanent dipole
• Ionic bonding occurs between a **metal** and a **non-metal** due to the TRANSFER of electrons, resulting in an ionic compound between two ions
• Ionic bonding is present when there are metal and non-metal ions in solution
• Ionic bonding is the **strongest** IMF, and nearly as strong as covalent bonding (the only **intramolecular** bond)