# Intermolecular Forces

**Unit 11C:** Types of Intermolecular Forces

### Knowledge/Understanding Goals:

* different types of intermolecular forces and what causes them

### Skills:

* rank attractions from strongest to weakest based on the type of intermolecular force

### Notes:

intramolecular forces: forces within a molecule (chemical bonds)

intermolecular forces: forces between molecules that cause attraction between neighboring molecules, influencing physical properties of the substance. Weaker than intramolecular forces.

soluble: when the attraction between solvent molecules and solute molecules or ions is strong enough to keep the solute distributed throughout the solvent.

miscible: when two or more liquids are soluble in each other.

Recall the 3 types of compounds:

ionic: compound made of ions (metal + nonmetal), which have charges with integer values (±1 or more)

covalent: compound made by sharing of electrons (usually all nonmetals),

metallic: compound made of metal atoms with delocalized electrons

### Types of intermolecular forces (IMF), strongest to weakest:

ion-ion: force of attraction between ions. Strength of force is based on Coulomb’s Law:



Bigger charges (larger values of *q*) mean stronger forces. (*E.g.,* the attraction between a +2 ion and a −3 ion will produce a force that’s six times as strong as the attraction between a +1 ion and a −1 ion.) If charges are the same, smaller atoms (smaller value of *d*) have stronger forces.

metallic bonds: metal atoms that delocalize their electrons and are held together by the “sea” of electrons surrounding them.

dipole-dipole: the force of attraction between opposing partial charges of two polar molecules (dipoles). Recall that the strength of attraction is based on the dipole moment (*μ*) of the molecule, given by the formula:

*μ = qd*

The partial charge (*q* ) is produced by the electronegativity difference (Δχ) between the two atoms of a polar bond.

Hydrogen bonds: The strongest type of dipole-dipole forces. Occurs in molecules that contain hydrogen (χ = 2.20) plus an element with an electronegativity larger than 3.0 (F, O, Cl, or N). The hydrogen bonds that hold water molecules together are what give water its unusual properties:

* + Water is more dense as a liquid than as a solid.
  + Water has an unusually high heat capacity (specific heat).
  + Water has a relatively high melting and boiling point. (Almost all covalent compounds with a molecular weight as light as 18 amu are gases.)
  + Water exhibits high surface tension and capillary action.
  + Water is known as the “universal solvent”.

London dispersion forces (Van der Waals forces): Random movement of electrons causes temporary dipoles to form within molecules, causing very weak attraction. (Named after the chemist Fritz London.)

London dispersion forces exist within all molecules, but they can only be observed when there aren’t any stronger forces present. The strength of the London dispersion forces is determined both by the average number of intermolecular contacts (a geometric consideration) and by the strength of those contacts (an electrostatic consideration). A rule of thumb that works for questions on the AP exam is that molecules with higher molecular mass usually have more electrons and therefore more intermolecular contacts, which produces stronger dispersion forces.

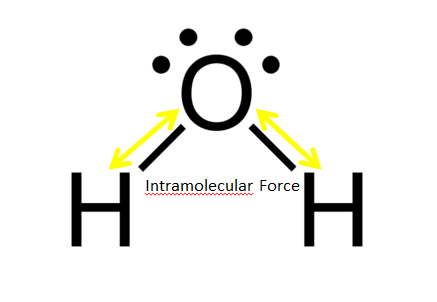
Greater surface area = Greater Van der Waals forces credit IMFs also exist between different types of molecules, such as ion-dipole attraction, or dipole-induced dipole attraction (*i.e.,* attraction between a dipole and a molecule that only experiences dispersion forces).

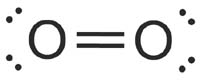
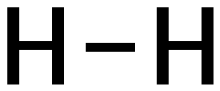
Each of these interactions would have an intermediate strength between the homogenous IMFs.

|  |  |  |
| --- | --- | --- |
| **Intermolecular Force** | **Type of Compound** | **Strength** |
| ion-ion | ionic (metal + nonmetal) | strongest |
| metal-metal | metallic (all metals) | ↕ |
| hydrogen bonds (strong dipole-dipole) | H with F, O, Cl, or N |
| dipole-dipole forces (other than hydrogen bonds) | polar covalent (all nonmetals) |
| dispersion | nonpolar covalent (all nonmetals) | Weakest |

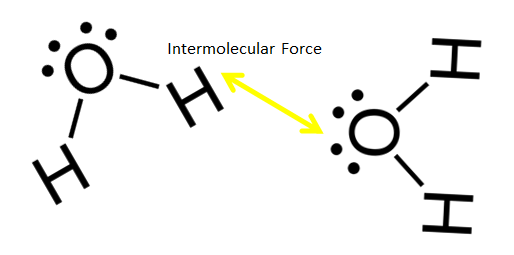
**IMF Effect on Physical Properties**

Recall that any process that breaks intramolecular forces is a chemical reaction, as you are breaking chemical bonds and creating new products.



→ +

Altering intermolecular forces influences how neighboring molecules interact with each other without changing the composition of the substance. Therefore, breaking intermolecular forces results in physical changes.



Intermolecular forces are responsible for many of the physical properties of chemical substances.

***Phase changes:*** The only difference between the solid, liquid and gaseous phases of a substance is the number of intermolecular forces keeping the particles of the substance in order.

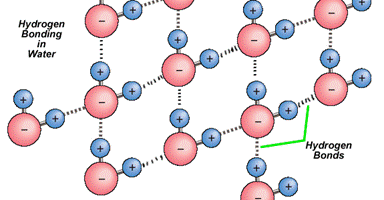
Ex: Ice Water Steam

Increased strength of IMF means more energy is required to break the molecules out of ordered attraction = higher melting and boiling temperatures.

Boiling Points: Ionic > Polar Covalent Molecules > Non-Polar Molecules

***Surface Tension & Adhesion***: Attraction between neighboring molecules accounts for their ability to “hold onto” each other to support force (surface tension) or to “pull” other molecules along as they move (cohesion).

***Ex***: Hydrogen bonding of water



Causes:

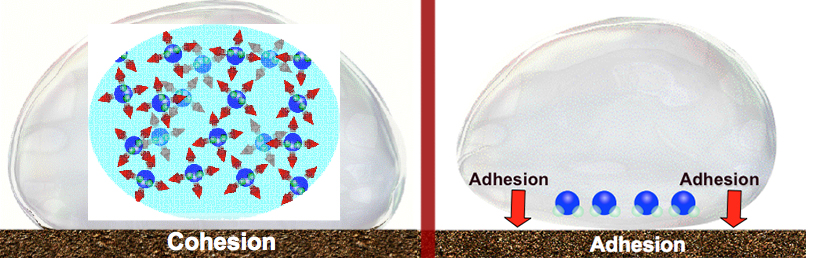
Surface tension (sticks to self at surface)

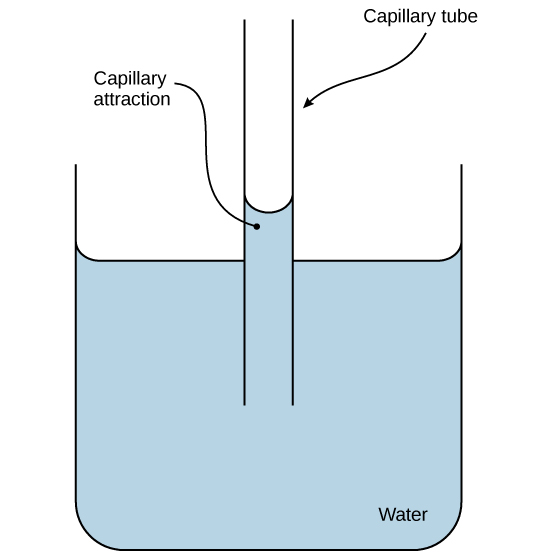


Cohesion (sticks to self internally)



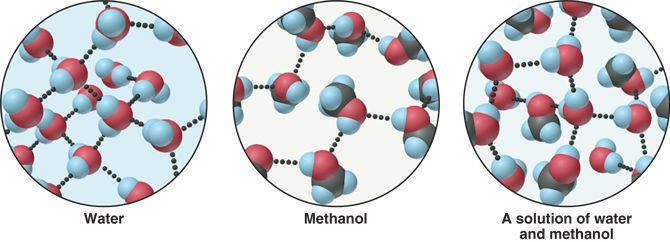
Adhesion (sticks to other matter)





## *Dissolving*: Because the molecules of polar liquids (especially those with hydrogen bonds) attract each other, polar liquids will:

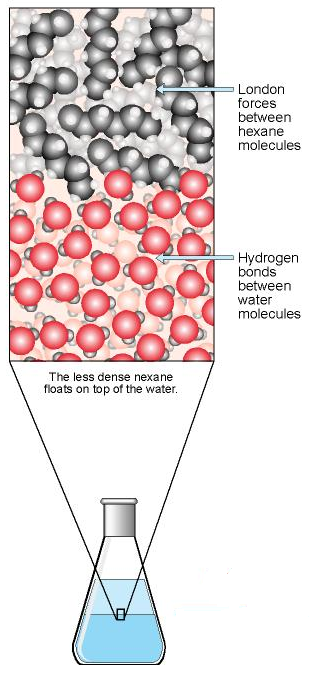
* + dissolve other polar liquids (The two liquids are said to be *miscible*.)



* + dissolve ionic salts (ionic compounds that can dissociate) or polar covalent molecules. *E.g.,* NaCl dissolves in H2O because the Na+ and Cl− ions dissociate.)

Ex: NaCl Glucose

In general, polar liquids can dissolve ionic compounds that have relatively small ion-ion forces (such as ions with +1 or −1 charges). Most polar liquids cannot dissolve most ionic compounds that have *only* charges larger than or equal to ±2. (However, note that there are *many* exceptions to this rule!)

Polar liquids will not dissolve non-polar liquids or other uncharged molecules. This is because polar liquids will form dipole-dipole bonds amongst themselves, pushing non-polar liquids out into a separate layer.

If you mix a nonpolar liquid and a polar liquid (such as oil and water), the liquids will form two separate phases. The popular expression to describe this phenomenon is “like dissolves like.”