Intermolecular Forces

Unit: Intermolecular Forces

MA Curriculum Frameworks (2016): HS-PS1-2, HS-PS1-3, HS-PS2-7(MA)

Mastery Objective(s): (Students will be able to…)

- Rank attractions from strongest to weakest based on the type of intermolecular force.

Success Criteria:

- Attractions are correctly identified and correctly ranked.

Tier 2 Vocabulary: polar

Language Objectives:

- Explain the different types of intermolecular forces and their relative strengths.

Notes:

intramolecular forces: forces within a molecule (chemical bonds)

intermolecular forces ("IMFs"): forces between molecules (solids & liquids). Weaker than intramolecular forces.

Note that both intramolecular forces (chemical bonds) and IMFs form because the process of these atoms or molecules coming together releases energy. If you wanted to separate the atoms/molecules/particles, you would need to add enough energy to make up for the amount of energy that was released.

Forming bonds always releases energy.
Breaking bonds always requires energy.

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 (usually 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

Use this space for summary and/or additional notes:

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

The stronger the IMFs, the higher the melting and boiling point of the compound, because you have to overcome the IMF in order to separate the molecules going from solid → liquid or liquid → gas.

ion-ion: force of attraction between ions. The strength of the force is based on Coulomb's Law:

$$F = \frac{kq_1q_2}{d^2}$$

where k is a constant, q_1 and q_2 are the strengths of the two charges, and d is the distance between them. 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 molecules (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 two polar molecules (dipoles). Recall that the strength of attraction is based on the dipole moment (μ) of the molecule, given by the formula:

$$\mu = qd$$

The partial charge (q) is produced by the electronegativity difference ($\Delta\chi$) between the two atoms of a polar bond.

hydrogen bonds: the strongest type of dipole-dipole forces. Occurs in molecules that contain hydrogen ($\chi = 2.20$) and 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".

Use this space for summary and/or additional notes:

London dispersion forces (induced dipoles): random movement of electrons causes temporary dipoles to form within molecules, causing very weak attraction. (Named after the chemist Fritz London.) All molecules have these dispersion forces, but they can only be observed when there aren't any stronger forces present. Because dispersion forces are attractions between electrons, molecules with more electrons (generally those with higher molecular mass) have stronger dispersion forces.

There can also be IMFs between different types of molecules:

ion-dipole attraction: attraction between an ion (full positive/negative charge) and a dipole (partial positive/negative charge). This attraction is stronger than dipole-dipole forces but weaker than ion-ion forces.

induced dipole: attraction between a permanent dipole and a compound that experiences only dispersion forces. The permanent dipole induces (creates) a temporary dipole in the other compound.

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

Use this space for summary and/or additional notes:

Polar *vs.* Nonpolar Solvents

Because the molecules 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 ions (from ionic compounds that can separate). *E.g.,* NaCl ions will dissolve in H_2O.

In general, polar liquids will not dissolve nonpolar liquids or other uncharged molecules.

In general, polar liquids can dissolve ionic compounds that have relatively small ion-ion forces (such as ions with +1 or −1 charges). In general, most polar liquids cannot dissolve most ionic compounds in which the charges of all of the ions are ±2 or higher. (However, note that this is a rule of thumb and there are *many* exceptions!)

Because polar liquids form dipole-dipole bonds, they will squeeze out nonpolar liquids. 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."

Use this space for summary and/or additional notes:

Homework Problems

For each pair of compounds:

- Write down the strongest intermolecular force that occurs in each of the two compounds.
- Circle the compound of each pair that would have the higher melting and boiling point (stronger intermolecular forces).
- Give the reason(s) for your choice.

1. NaCl HCl

2. CaS KCl

3. H_2O N_2O

4. CO CO_2

5. HBr HF

6. CH_4 C_8H_{18}

Use this space for summary and/or additional notes: