

AP Chem - Unit 7 - IMF

Worksheet 15 - Intermolecular Forces

→ Ionic metallic Bonds
covalent

Chemical bonds are **intramolecular** forces which hold *atoms* together as molecules. The forces that hold *molecules* together in the liquid and solid states are called **intermolecular** forces.

Intermolecular forces (IMF) can be qualitatively ranked using Coulomb's Law:

$$\text{force} \propto \frac{Q_1 Q_2}{r^2}$$

where Q_1 and Q_2 are charges and r is the distance between them.

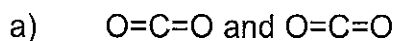
The obvious consequences of this relationship are that:

- the bigger the charges, the stronger the interaction
- the closer the charges, the stronger the interaction

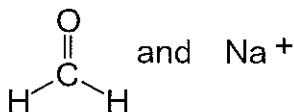
The charges in chemical species can be classified as:

- ionic** - full positive and negative charges
- dipole** - partial positive or negative charges, resulting in polarized bonds in which there is unequal sharing of valence electrons. This arises when electronegative elements (O, N, halogens) are bonded to less electronegative species. **Molecular geometry** also plays a role in determining the net **dipole moment** of a molecule.
- London Dispersion Forces (LDF)** - instantaneous dipole moments resulting from the motion of electrons in an atom or molecule. All atoms and molecules possess LDF, which increase with the number of electrons in the molecule, and its shape. These are very small, very short-lived charges. Also called Induced dipole - Induced dipole or Dispersion (short Hand)

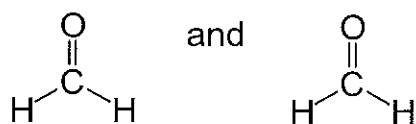
- List **all** types of IMF which would be exhibited between the pairs of species shown below?



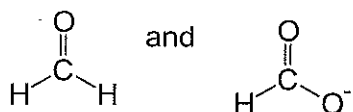
b)



c)

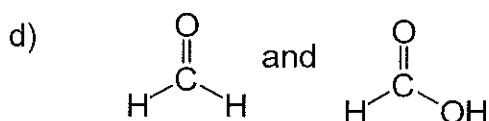
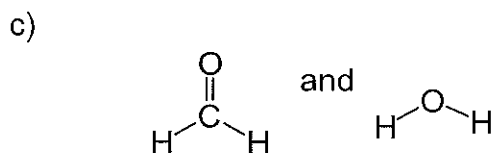
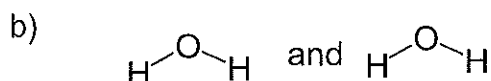
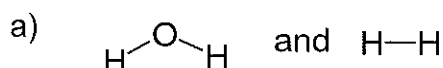


d)



There is one type of **dipole-dipole** interaction which is especially strong. It is called a **hydrogen bond** (H-bond). The partial negative charge (δ^-) comes from one of the electronegative elements **F**, **O** or **N**. These are called H-bond **acceptors**. The partial positive charge (δ^+) comes from an **H** bonded **directly** to one of these elements (**O-H**, **N-H**, **F-H**). These are called H-bond **donors**. Both a donor and an acceptor are needed to form an H-bond. These are stronger IMF than dipole-dipole interactions, but not as strong as ion-dipole interactions. ** Don't mix up Bonded H, a Intramolecular Bond, in a molecule with a H-Bond an Intermolecular*

2. Which of the following pairs of compounds can form H-bonds? For those that can, mark the position of the partial positive (δ^+) and negative (δ^-) charges in the molecules and indicate where the H-bonds will form. For those that can't form H-bonds, describe the strongest IMF available to that pair of compounds.



3. What is the nature of the major attractive IMF in the following molecules?
Please draw a Lewis structure and determine the shape of each molecule.

- | | |
|----|----|
| a) | d) |
| b) | e) |
| c) | |

It requires energy to pull molecules apart in going from the solid to liquid to gaseous states. The stronger the IMF, the more energy must be added, the higher the phase transition temperature will be.

4. Which of the following substances is most likely to exist as a crystalline solid at room temperature? Of the gases, which would be the hardest to condense to a liquid under pressure?

Rank these substances from lowest to highest intermolecular forces

- | | |
|----------------------|--------------------|
| a) HF | d) SO ₂ |
| b) PCl ₃ | e) F ₂ |
| c) FeCl ₂ | |

5. Which of the following is expected to have the highest boiling point?
Which is expected to have the lowest?

Rank these substances from lowest to highest intermolecular forces

- | | | |
|--------------------|---------------------|--------------------|
| a) CO ₂ | b) Ar | c) CF ₄ |
| d) LiCl | e) SiF ₄ | |

In general, be careful when comparing molecules with very different structures and/or molecular weights. For example, H_2O is a liquid at room temperature and I_2 is a solid. This doesn't mean that H-bonding, in general, is weaker than LDF. It's just that the structures are too different to compare.

6. Give an explanation in terms of IMF for the following differences in boiling point.

a) HF (20°C) and HCl (-85°C)

b) CHCl_3 (61°C) and CHBr_3 (150°C)

c) Br_2 (59°C) and ICl (97°C)

7. Indicate which of the following properties will increase, decrease or remain unaffected by an increase in the strength of the intermolecular forces?

a) vapor pressure (pressure of gas above a liquid sample in a closed container)

b) normal boiling point (boiling point at 1 atmosphere pressure)

c) heat of vaporization (heat requires to take a liquid sample to the gaseous phase)

d) surface tension (adhesion of molecules)