**Intermolecular Forces 5.1**

Types of intermolecular forces
Determining relative boiling points

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**Intramolecular vs. Intermolecular Forces**

Intramolecular Forces are bonds.

[Diagram of intramolecular forces]

Intermolecular Forces are forces of attraction between molecules.

[Diagram of intermolecular forces]

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**Ion-Dipole**

- The forces of attraction between an ion and a polar molecule.

[Diagram of ion-dipole forces]

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**Na\(^+\)\(_{aq}\) and Cl\(^-\)\(_{aq}\)**

[Image of Na\(^+\) and Cl\(^-\) ions]

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**Dipole - Dipole**

The attractive forces between the negative end of one polar molecule and the positive end of another polar molecule.

[Diagram of dipole-dipole forces]

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**Hydrogen Bonds**

A type of Dipole - Dipole

- Occurs between a Hydrogen that is covalently bonded to Fluorine, Oxygen, or Nitrogen and another F, O, or N with at least one lone pair

[Diagram of hydrogen bonds]

- Five to ten times stronger than other dipole-dipole attractions

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Hydrogen Bonds

Why are H-Bonds so strong?

1) F – H, O – H, and N – H bonds are very polar.
2) These atoms are very small, so the partial charges caused by the difference in electronegativity is highly concentrated.
3) The lone pair(s) on F, O, or N increases the already partially negative charge on these atoms, thereby creating a stronger attraction for the slightly positive hydrogen.

Hydrogen Bonds Between Water Molecules

Hydrogen Bonds Between Water and Methanol

Both form H-Bonds

Hydrogen Bonds in Acetamide

Forms two H-Bonds with itself

Boiling Point (221°C)

Ethan alcohol does not form Hydrogen Bonds

This structure does not form H-Bonds.

Hydrogen is bonded to Carbon.
Hydrogen needs to bond with F, O, or N to form an H-bond.

Hydrogen Bonds

Only molecules with H-bonds on this graph

Boiling Temperature vs. Period

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Ion Induced Dipole

- Electrons are attracted to the positive charge
- Electron density is greater here for brief spurts
- It continually flips between being polar and non-polar

Dipole Induced Dipole

- Polar Molecule
- Non-Polar Species
- Polar Molecule
- Polarized Molecule

London Dispersion Forces

- These forces exist between all species: atoms, ions, non-polar and polar molecules.
- Contribute to the overall force of attraction between all particles.
- London Dispersion Forces are the only intermolecular forces that keep assemblages of non-polar species together.

London Dispersion Forces

- Averaged over time, this atom is non-polar.
- Instantaneous charge distributions are polar.

Larger species with more electrons are more polarizable.
Larger species with more electrons are more polarizable.

- They have a weaker hold on their outer electrons.
- When moving down a group, or constructing molecules with more atoms, the resulting species has more electrons and is larger.
  - The more electrons a species has, the more polarizable it is.
  - This is not always true when moving from left to right across a period, as atomic radius decreases.

Intermolecular Forces of Attraction

- ion-ion
- ion-dipole
- H-bonds
- dipole-dipole
- ion-induced dipole
- dipole-induced dipole
- London dispersion

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Ex1) Which species has the higher boiling point? Identify the intermolecular forces acting on each.

\[
\begin{array}{c|c}
\text{C}_2\text{H}_6 & \text{C}_3\text{H}_8 \\
\hline
\text{Both are Non-Polar} & \\
\text{The larger molecule has the higher BP, as larger molecules are more polarizable.} & \\
\text{Only London dispersion forces act on these molecules.} & \\
\text{BP}_{\text{C}_2\text{H}_6} = -89^\circ\text{C} & \text{BP}_{\text{C}_3\text{H}_8} = -42^\circ\text{C}
\end{array}
\]

Ex2) Which species has the higher boiling point? Identify the intermolecular forces acting on each.

\[
\begin{array}{c|c}
\text{H} & \text{H} \\
\hline
\text{H-C-C-O-H} & \text{H}_3\text{C}_2\text{H}_8 \\
\text{H} & \\

\end{array}
\]

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Ex3) Which species has the higher boiling point? Identify the intermolecular forces acting on each.

\[
\begin{array}{c|c|c}
\text{H} & \text{H} & \text{H} \\
\hline
\text{H} & \text{H} & \text{H} \\
\text{H-C-C-O-H} & \text{H} & \text{OH} \\
\end{array}
\]

Ex4) Which has the higher melting point? Identify the intermolecular forces acting on each.

\[
\begin{array}{c|c}
\text{CH}_4 & \text{Cl}_4 \\
\end{array}
\]

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Ex5) Which species has the higher boiling point? Identify the intermolecular forces acting on each.

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