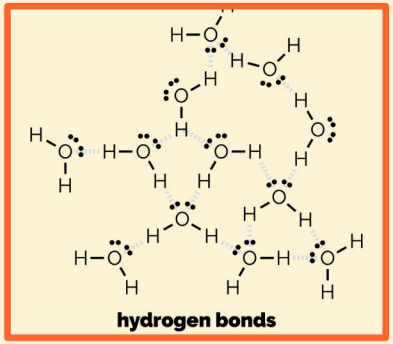
HIGHLIGHTS

- Interactions between the same molecules:
  - Boiling points
- Interactions between different molecules
  - Like-dissolves-like
  - Solubility
  - Miscibility



The physical properties of molecules are influenced by the non-covalent interactions or intermolecular forces that occur between molecules. This can occur between identical molecules, leading to high boiling or melting points. Or the interactions could act between molecules of different chemical species, and this can help explain properties like miscibility or solubility. The interactions were described in a previous summary and handout. This handout describes their effects.

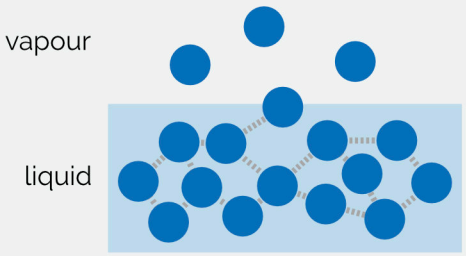
CHEMISTRY CLASSICS

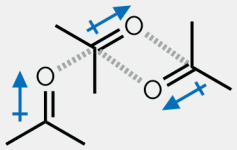
NON-COVALENT INTERACTIONS

PHYSICAL PROPERTIES

Non-Covalent Interactions & Physical Properties

1. Boiling Points

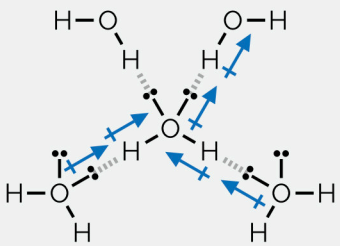




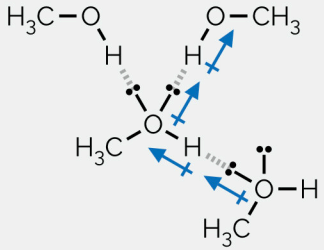
acetone (MW 58)
dipole-dipole interactions *bp 56 °C*

butane (MW 58)
dispersion forces bp -1 °C

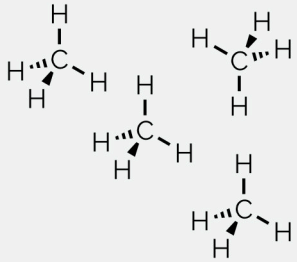
A liquid boils if it is given sufficient energy to break the attractive (non-covalent) interactions between molecules. The stronger the interactions, the higher the boiling point (bp).



water bp 100 °C
strong H-bonding

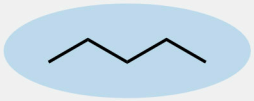


methanol bp 65 °C
one less H-bond

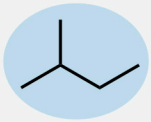


methane bp -162 °C
no H-bonding

Non-covalent interactions are additive - more hydrogen bonding leads to higher bp.



pentane bp 36 °C
largest surface area
more dispersion forces



2-methylbutane bp 28 °C
smaller surface area
less dispersion forces

2,2-dimethylpropane bp 10 °C
smallest surface area
least dispersion forces

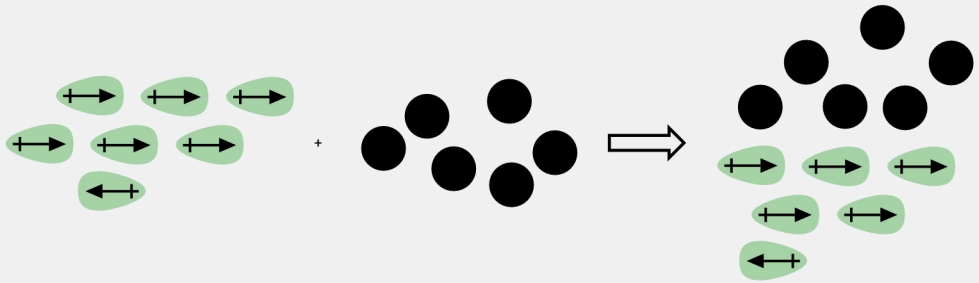
The shape of a molecule determines the size of non-covalent interactions. The larger the surface area the more polarizable a molecule (larger momentary dipole), & the more interactions between molecules. Bigger surface area greater dispersion forces & higher boiling point.

The shape of molecules partially explains the difference between oils and fats. Fats are straight molecules that easily interact through numerous dispersion forces. They have high melting points & are solids. Oils are kinked and cannot approach as close to each other. They have fewer dispersion interactions and are liquids.

2. Solubility & Miscibility

Solubility describes a solid dissolving in a liquid. ***Miscibility*** the mixing of two liquids. Both are simplistically summarized as "***like dissolves like***"

no mixing *- non-polar substance doesn't break strong interactions between polar molecules*

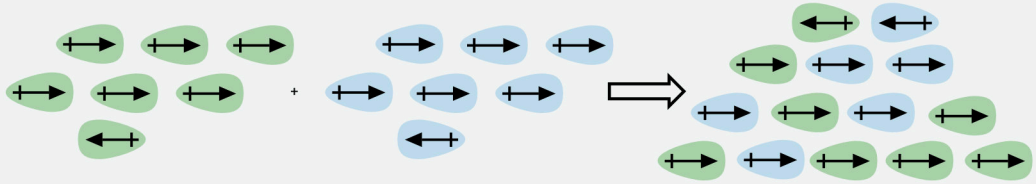


polar molecules
strong interactions

non-polar molecules
weak interactions

polar + non-polar
no interactions between the two

mixing *- polar molecules form strong interactions with other polar compounds allowing mixing*



polar molecules
strong interactions

polar molecules
strong interactions

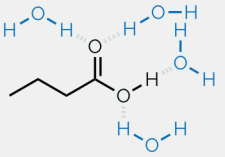
polar + polar
strong interactions

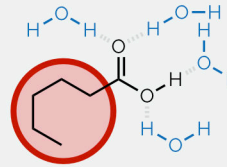
Hydrophilic compounds - are polar & mix with water. They interact strongly with water, disrupting attractions between water molecules.

Hydrophobic molecules - are non-polar. They are not attracted to water. They cannot break the existing interactions. They mix with other non-polar molecules as there are no strong interactions to break.

3. Polarity & Solubility are on a Scale

butanoic acid
miscible in H_2O
smaller non-polar chain allows polar acid to dominate properties





hexanoic acid
1.08 g/100 ml H_2O
larger non-polar chain dominates properties

Many students want compounds to be polar or non-polar, soluble or not soluble. But polarity is a scale. Two polar compounds can have different solubilities as one is more polar than the other. Both molecules above are carboxylic acids (polar, capable of hydrogen bonding) but one is soluble while the other is only partially soluble.