
Chapter 12. Intermolecular Forces: Liquids, Solids, and Phase Changes.

Intermolecular Attractive Forces:

Intermolecular forces are often referred to as _____.

All intermolecular forces are _____ in nature. That is, they involve the attraction of a _____ charge for a _____ charge.

Identifying intermolecular attractive forces allow us to

Review of Dipole Moment

1. A polar molecule is one with an unequal distribution of _____ as a result of its _____ and _____.
2. A polar molecule has _____.
3. In order to determine if a molecule is polar, you must know its _____.
4. Two ways to determine if a molecule is polar:

5. Examples:



6. One useful generalization: hydrocarbons are _____.

Four types of intermolecular attractive forces:

- 1.
- 2.
- 3.
- 4.

Dipole-Dipole Attractions

- exist between _____ molecules
- For molecules of approximately equal molecular mass and size, dipole-dipole attractions increase with increasing _____:

compound	molar mass	dipole moment (μ)	boiling point ($^{\circ}\text{C}$)
$\text{CH}_3\text{CH}_2\text{CH}_2$	44	0.08 D	-42°
CH_3OCH_3	46	1.30 D	-24°
CH_3CHO	44	2.69 D	20°
CH_3CN	41	3.92 D	82°

- Example: Which substance is expected to have the higher boiling point, CO_2 or HCl ?

Hydrogen Bonds

- A hydrogen bond is an _____ between a _____
_____ on one molecule and a _____
_____ on an adjacent molecule.

polarized hydrogen:

a very electronegative atom:

example:

- A special case of _____.
- Hydrogen bonding is an important source of intermolecular attractions in compounds containing _____, _____, and _____ bonds.
- Example:
- Substantial energy is required to overcome hydrogen bonds. Thus, substances which hydrogen bond generally exhibit these properties:

- Hydrogen bonding is responsible for:
 - 1)
 - 2)
 - 3)

London Dispersion Forces

- Attractive forces due to _____
- Large atoms and molecules are more easily polarized than small atoms and molecules; thus, London forces _____ with molecular size.
- Generally, in the absence of other effects, substances consisting of large atoms and molecules will have _____ melting points and boiling points than comparable substances which are smaller.
- Dispersion forces are present in _____ and _____ molecules.

Example: Place the diatomic halogens in order of increasing boiling point.

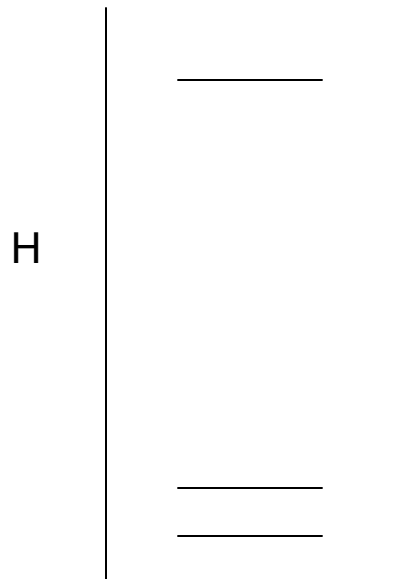
Summary of intermolecular attractive forces:

- Everything else being equal, which intermolecular attractive force is the strongest?
“everything else being equal” means
- Everything else being equal, which intermolecular attractive force is the weakest?
“everything else being equal” means
- What types of intermolecular forces are present in
 - CH₃OH(l)
 - CH₃CH₂CH₂CH₂CH₂CH₃(l) (hexane)
 - H₂S(l)

Attractive Force	Particles	Examples
ion-dipole	ion-polar molecule	NaCl dissolved in H ₂ O
dipole-dipole	polar molecules	ICI, HCl, H ₂ S
Hydrogen bonding	molecules containing H bonded to F, O, or N	H ₂ O molecules H ₂ O - CH ₃ CH ₂ OH solution
London dispersion forces	nonpolar molecules (present in all molecules)	n-hexane molecules, Cl ₂ ,
ionic (solids)	cations and anions	NaCl, KNO ₃

Phase Changes and Other Properties Indicative of Intermolecular Attractions

- 1) Know the names for the phase changes and whether these are endothermic or exothermic.



2) ΔH°_{vap} and ΔH°_{fus}

ΔH°_{vap}

ΔH°_{fus}

Two points:

- In general, the stronger the intermolecular forces the _____ ΔH°_{vap} and ΔH°_{fus} .
- For a given substance, which is generally greater, ΔH°_{vap} or ΔH°_{fus} ? Why?

3) *Vapor pressure*

Thought experiment:

Definition of vapor pressure (memorize this!):

The *stronger* the intermolecular attractive forces, the _____ the vapor pressure.

A liquid is considered *volatile* if it has _____.

The stronger the intermolecular attractive forces, the _____ volatile the substance.

Example: gasoline (largely a mixture of hydrocarbons) vs ethylene glycol

4) *Boiling point--*

Normal Boiling Point--

The stronger the intermolecular attractive forces, the _____ the boiling point.

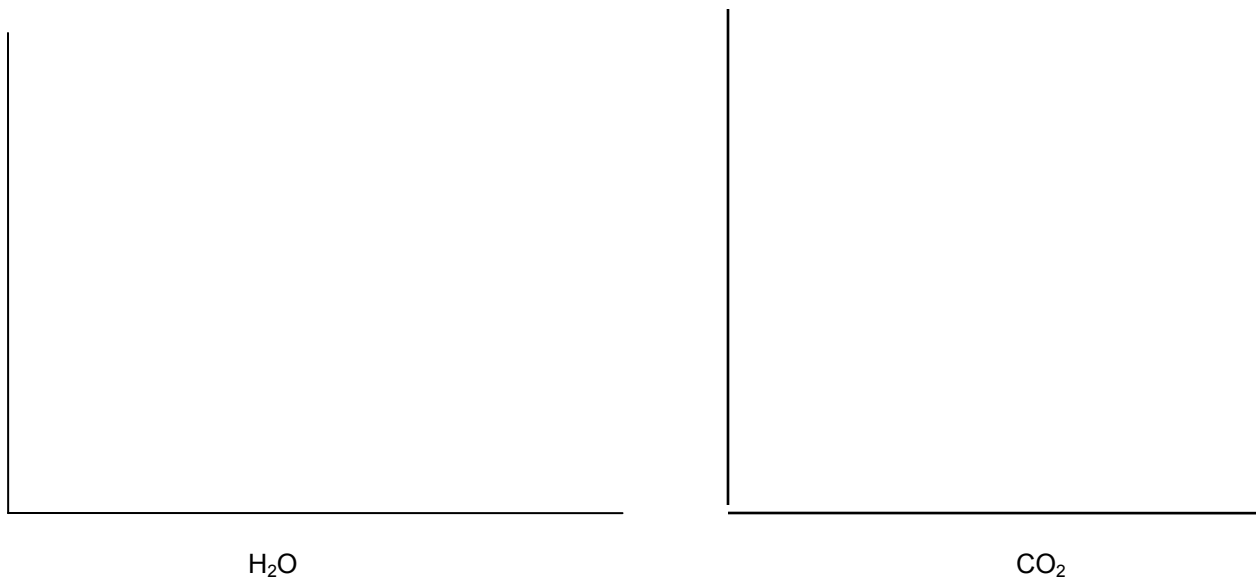
5) Melting point/freezing point--temperature at which solid and liquid states are _____.

The stronger the intermolecular forces, the _____ the melting point.

6) Other properties of the liquid state which are indicative of intermolecular attractive forces:

Heating and Cooling Curves

Phase Diagrams



Draw the phase diagrams of water and carbon dioxide above, and identify the following points or regions:

- Fusion Curve
- Sublimation Curve
- Vaporization curve
- Triple Point
- Critical Point
- Critical Temperature
- Critical Pressure
- Supercritical Fluid