



Intermolecular Force: The Force that holds molecules and atoms together in a liquid or solid state. Strength determines type of state

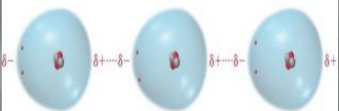
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Dispersion Force

An instantaneous dipole on any one helium atom induces instantaneous dipoles on neighboring atoms, which then attract one another.



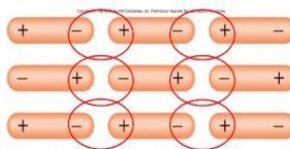
Temporary weak dipole interactions that can occur in nonpolar and polar molecules

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Orientation of Polar Molecules in a Solid



Dipole-Dipole Interaction

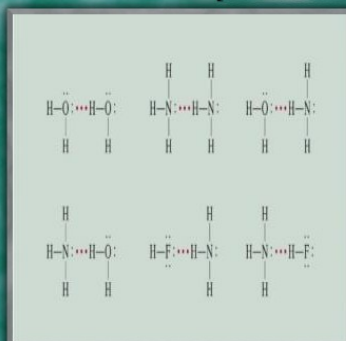
The positive end of a polar molecule is attracted to the negative end of its neighbor.



Dipole-Dipole Interaction B/W Polar Molecules that is permanent. It is determined by geometry

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H Bonds

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TABLE 12.4 Types of Intermolecular Forces

Type	Present in	Molecular perspective	Strength
Dispersion	All molecules and atoms		0.05-20+ kJ/mol
Dipole-dipole	Polar molecules		2-20+ kJ/mol
Hydrogen bonding	Molecules containing H bonded to F, O, or N		10-40 kJ/mol
Ion-dipole	Mixtures of ionic compounds and polar compounds		30-100+ kJ/mol

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Intermolecular interactions IRL

- **Surface tension** is a property that results from the tendency of liquids to minimize their surface area



- **Viscosity** is the resistance of a liquid to flow



Viscosity of Water and Honey

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More macro-phenomena from intermolecular forces

- **Capillary action** is the ability of a liquid to flow up a thin tube against the influence of gravity
 - **Cohesive** forces hold the liquid molecules together
 - **Adhesive** forces attract the outer liquid molecules to the tube's surface



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Summarizing the Process of Vaporization

- Rate of vaporization increases with increasing temperature
- Rate of vaporization increases with increasing surface area
- Rate of vaporization increases with decreasing strength of intermolecular forces

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Condensation

- Some molecules of a vapor lose energy through molecular collisions
- Some of these molecules will get captured back into the liquid when they collide with its surface
- Some may stick and gather to form droplets of liquid, particularly on surrounding surfaces
 - **condensation is an exothermic process**

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CHEM 1120- 12.5 Prob.1

[SPELL CARD]

Calculate the mass of water (in g) that can be vaporized at its boiling point with 155 kJ of heat.

The heat of vaporization for water ΔH_{vap} is +40.7 kJ/mol at 100°C.

$$155 \text{ kJ} \cdot \frac{1 \text{ mol H}_2\text{O}}{40.7 \text{ kJ}} = 3.81 \text{ mol H}_2\text{O}$$

$$3.81 \text{ mol H}_2\text{O} \cdot \frac{18.0 \text{ g}}{1 \text{ mol H}_2\text{O}} = 68.7 \text{ g H}_2\text{O}$$

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CHEM 1120- 12.5 #3

[SPELL CARD]

Heat of Vaporization

- Liquids that evaporate easily are said to be **volatile**
 - For example, gasoline and fingernail polish remover
- Liquids that do not evaporate easily are **nonvolatile**
 - For example, motor oil
- The amount of energy required to vaporize one mole of liquid is called the **heat of vaporization, ΔH_{vap}**
 - Or enthalpy of vaporization
- It is always endothermic; therefore, ΔH_{vap} is positive
- It is somewhat temperature dependent

$$\Delta H_{\text{condensation}} = -\Delta H_{\text{vaporization}}$$

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CHEM 1120- 12.5 #4

[SPELL CARD]



- Once the rates of vaporization and condensation are equal, the total amount of vapor and liquid will not change (at constant T)
- Evaporation and condensation are still occurring, but there is no net gain or loss of either vapor or liquid

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CHEM 1120- 12.5 #5

[SPELL CARD]

Vapor pressure

- Pressure exerted by the vapor when it is in dynamic equilibrium with its liquid is called the **vapor pressure**
- The weaker the attractive forces between the molecules, the more molecules will be in the vapor
 - Therefore, the weaker the attractive forces, the higher the vapor pressure
 - The higher the vapor pressure, the more volatile the liquid

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CHEM 1120- 12.5 #6

[SPELL CARD]

- The **normal boiling point** of a liquid is the point at which the vapor pressure of the liquid equals the atmospheric pressure

TABLE 12.8 Boiling Points of Water at Several Locations of Varied Altitudes

Location	Elevation (ft)	Approximate Pressure (atm)	Approximate Boiling Point of Water (°C)
Mount Everest, Tibet (highest mountain peak on Earth)	29,035	0.23	78
Mount McKinley (Denali), Alaska (highest mountain peak in North America)	20,320	0.46	83
Mount Whitney, California (highest mountain peak in the contiguous United States)	14,505	0.60	87
Denver, Colorado (mile-high city)	5,280	0.83	94
Boston, Massachusetts (sea level)	20	1.0	100

*The atmospheric pressure in each of these locations is subject to weather conditions and can vary significantly from these values.

As liquid is heated to boiling point, it stops heating. The heat is added to the boiling. Temperature increases again once all liquid is turned to gas

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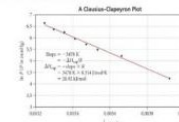
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[SPELL CARD]

Clausius-Clapeyron Equation

- The natural logarithm of the vapor pressure ($\ln P_{\text{vap}}$) versus inverse temperature ($1/T$) is a linear function
 - A graph of $\ln P_{\text{vap}}$ versus $1/T$ is a straight line
 - The slope of the line: $-\Delta H_{\text{vap}} / R$
 - Where R is 8.314 J/mol · K



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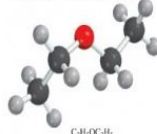
CHEM 1120- 12.5 Prob.2

[SPELL CARD]

Diethyl ether is a volatile, highly flammable organic liquid that is used mainly as a solvent.

The vapor pressure of diethyl ether is 401 mmHg at 18°C. The heat of vaporization (ΔH_{vap}) is 26.0 kJ/mol. Calculate its vapor pressure at 32°C.

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$$\ln(P_2/P_1) = -\Delta H_{\text{vap}}/R \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$\ln(P_2/401 \text{ mmHg}) = -26.0 \text{ kJ/mol} / (8.314 \text{ J/K} \cdot \text{mol}) \left(\frac{1}{305 \text{ K}} - \frac{1}{291 \text{ K}} \right)$$

$$\ln(P_2/401 \text{ mmHg}) = -0.494$$

$$P_2 = e^{-0.494} \cdot 401 \text{ mmHg}$$

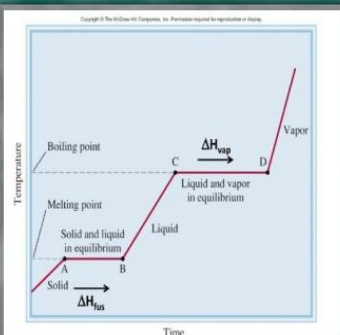
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[SPELL CARD]



Sublimation is Solid to Gas, reverse is deposition
Fusion is melting; it is endothermic
Does not need all solids to be melted for T to rise

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CHEM 1120- 12.8

[TRAP CARD]

Water: an extraordinary substance

- A liquid at room temperature
 - Most molecules with similar molar masses are gases at room temperature
 - This is due to H-bonding (4 at a time)
- An excellent solvent
 - Dissolves many ionic and polar molecules
 - Has a large dipole moment
 - Even many small nonpolar molecules have some solubility in water, for example: O_2 , CO_2
- Has a very high specific heat
 - Moderating effect on coastal climates (review 10.4)
- Expands when it freezes at a pressure of 1 atm
 - Ice is less dense than liquid water

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