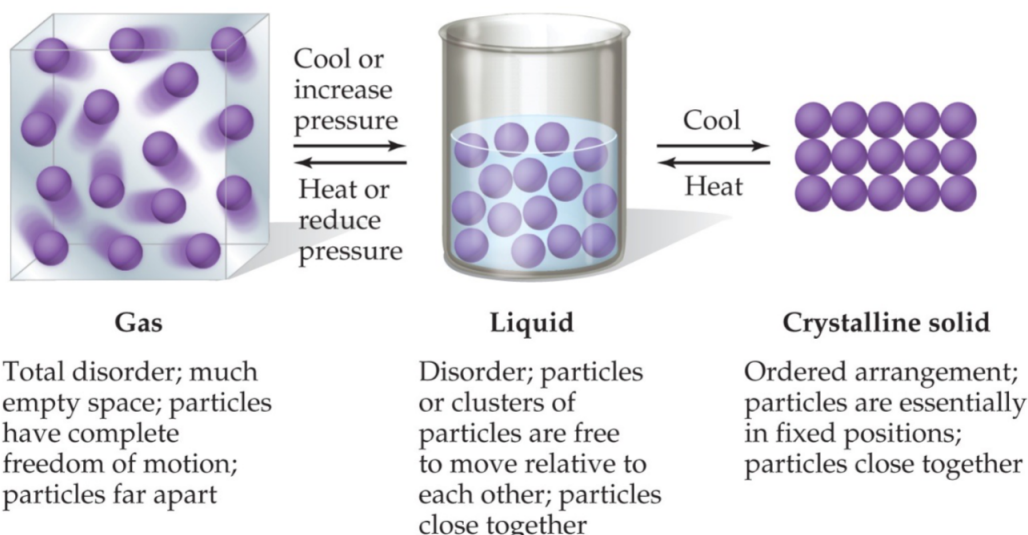# CHEM 20B Week 2

Aidan Jan

January 29, 2024

States of Matter

The fundamental difference between states of matter is the distance between particles.

Molar Volume

$$V_m = \frac{V}{n}$$

- For 1 mole of solid or liquids $V_m = 10 \sim 100$ cm^3 at room conditions
- For 1 mole of gas, $V_m \approx 24000$ cm^3 at room conditions

Compressibility

κ (kappa) = fractional change in volume per pressure change, when T is fixed.

$$\kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$$

$$\kappa = -\frac{1}{V}\left(\frac{\Delta V}{\Delta P}\right)$$

κ (Gases) is large. κ (Solids/Liquids) $\sim 10^{-4}$/atm, much smaller than for gases.
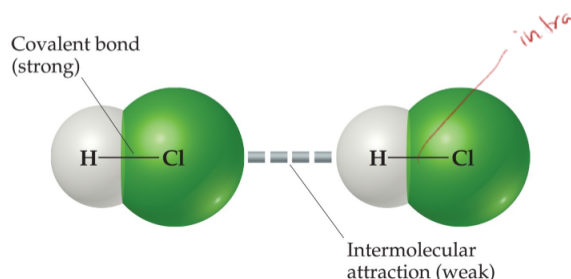
Thermal Expansion

The thermal expansion coefficient measures the percent change in volume when we raise the temperatrue.
α (alpha) = fractional change in volume / temperature change.

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$
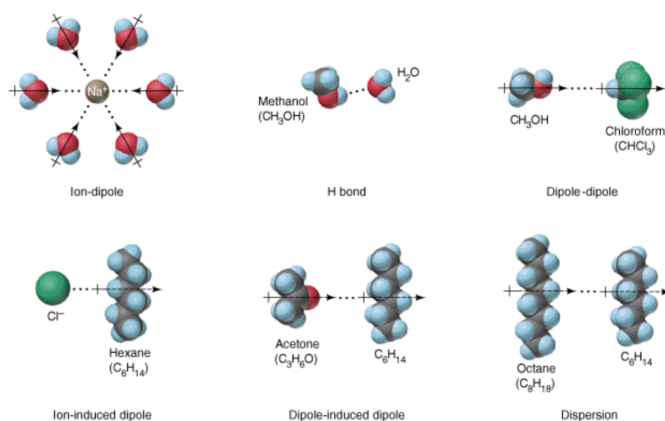
$$\alpha = \frac{1}{V}\left(\frac{\Delta V}{\Delta T}\right)$$

Intermolecular Forces

The attractions between molecules are not nearly as strong as the intramolecular attractions that hold compounds together.

They are, however, strong enough to control physical properties such as boiling and melting points, vapor pressures, and viscosities.

Types of Intermolecular Forces

- Ion-Ion Forces
- Dipole-Dipole Forces
- Ion-Dipole Forces
- Charged-Induced Dipole Forces: Polarizability
- Induced Dipole - Induced Dipole Forces: London Dispersion Forces
- Repulsive Forces

Ion-Ion Forces

- Ċolumbic̈; i.e., due to attraction between opposite charges

- Long range $\sim 1/R$

- Not directional (does not depend on relative orientation, each ion interacts equally strongly with neighboring ions on all sides)

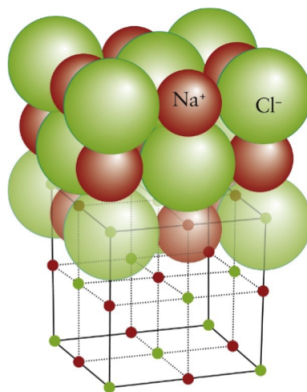- Strong (the same strength as covalent interactions)

- Example: NaCl

Figure 3H.28
Atkins, Chemical Principles: The Quest for Insight, 7e
W. H. Freeman & Company, © 2016 by P. W. Atkins, L. L. Jones, and L. E. Laverman
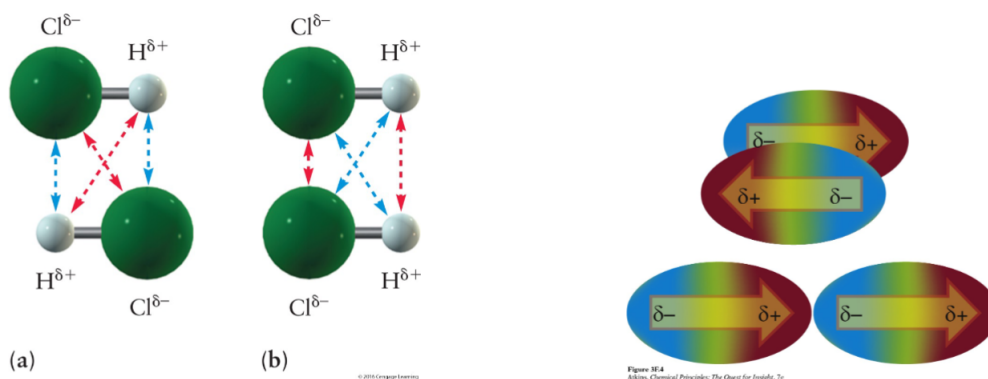
Ion-Dipole Forces

- Act between ions and molecules with permanent dipole moments.

- Stronger than dipole-dipole, weaker than ionic

- Long range $\sim 1/R^2$

- Directional (a rotation of the dipole by 180 degrees turns the interaction from attractive to repulsive, or vice versa).

- Example: Water being attracted to ions
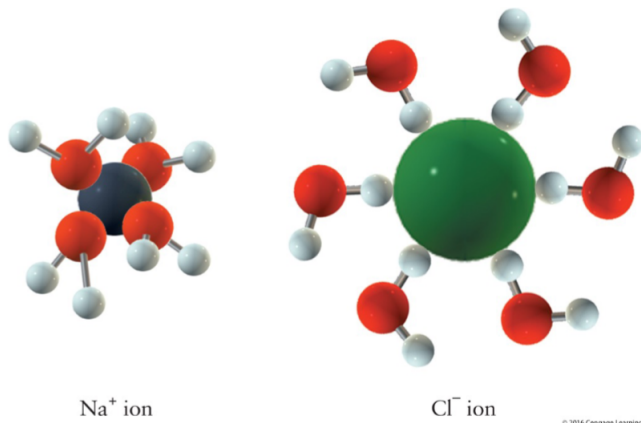
Na^+ ion Cl^- ion
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Dipole-Dipole Forces

- The dominant force between polar molecules.

- Long range $\sim 1/R^3$ but not as long-range as ion-ion or ion-dipole

- Relatively strong: $\sim$ 5-50 kJ/mol

- Directional

- Example: HCl molecules aligning in opposite directions

Charge-Induced Dipole Forces: Polarizability

- The electrons in a nonpolar molecule are distributed symmetrically, the distribution can be distorted by an approaching electrical charge.

- Na^+ induces a temporary dipole moment in the Ar atom

- The electron distribution of the nonpolar molecule is said to be polarizable

- Weak

- Short range
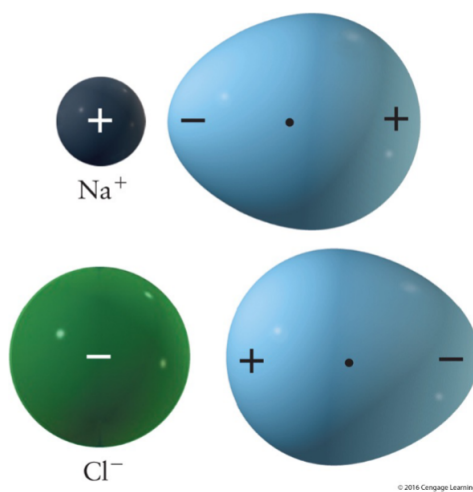
Induced Dipole - Induced Dipole Forces: London Dispersion Forces

- **Instantaneous dipole moments** create distortions in the electron cloud, which become partially positively (δ^+) and partially negatively (δ^-) charged.

- Always attractive

- It is not very directional (i.e., even for molecules, the interaction does not depend much on the relative orientation of the molecule).

- Very short-range, $1/R^6$

- Since always attractive, adds up. Can be significant for large surfaces - causes two regions with large surface area that are placed near each other to stick together.
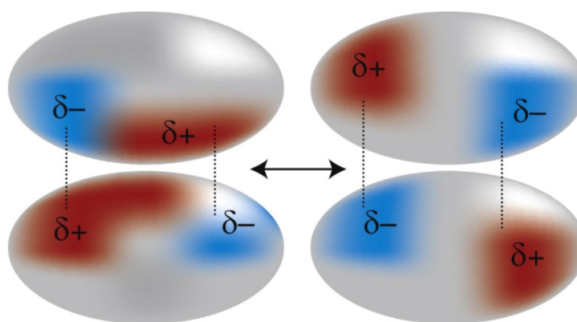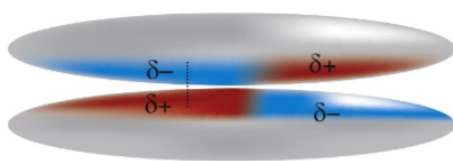
- The only force present for nonpolar molecules

Figure 3F.7
Atkins, *Chemical Principles: The Quest for Insight*, 7e
W. H. Freeman & Company, © 2016 by P. W. Atkins, L. L. Jones, and L. E. Laverman

London Dispersion Forces: Size and Shape

- As size increases (more shells), polarizability increases. This causes melting and boiling points to increase.

- Rod-like molecules have a **greater surface area**, which allow for **more contact points** for molecules to join togerther.

- Ball or spherical shaped molecules have **fewer contact points** for molecules to join together.
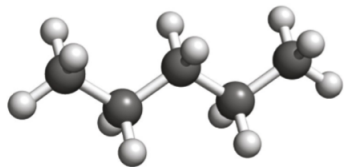

(a)
Figure 3F.9a
Atkins, *Chemical Principles: The Quest for Insight*, 7e
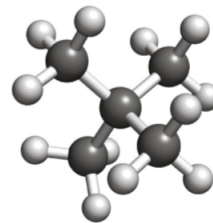W. H. Freeman & Company, © 2016 by P. W. Atkins, L. L. Jones, and L. E. Laverman
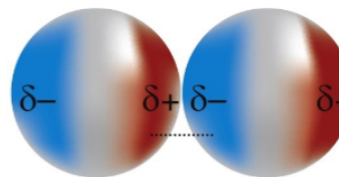
(b)
Figure 3F.9b
Atkins, *Chemical Principles: The Quest for Insight*, 7e
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8 Pentane, C_5H_{12}

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Boiling Point: 36°C

9 2,2-Dimethylpropane, $C(CH_3)_4$

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(isomers)   10°C

Continued in Week 3...