Intermolecular Forces & Phase Changes

Chapter 12

Definition

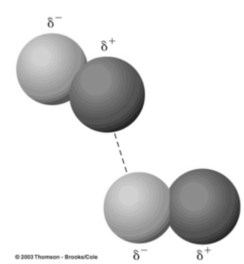
- Intermolecular forces are the forces between atoms, molecules, and ions that hold solids and liquids together.
- Intermolecular forces also play a part in the solubilities of substances.

Ion-dipole forces

- Attraction of an ion to one side of a polar molecule.
- This interaction allows water to easily dissolve many ions.

Dipole-Dipole forces

- Attraction of the oppositely charged sides of polar molecules.
- May occur between molecules of the same or different compounds

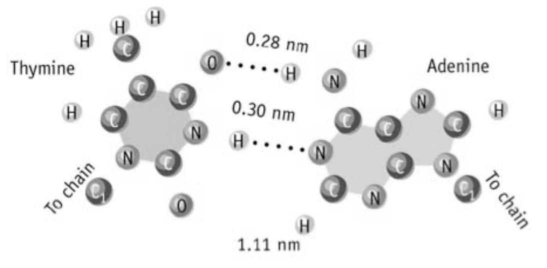


Dipole – dipole special case: Hydrogen bonding

- A hydrogen bond is an especially strong dipole-dipole interaction. This is not a “bond” like a covalent bond.
- Occurs when hydrogen is covalently bound to N, O, or F (all small, very electronegative atoms) and has a dipole-dipole interaction with a highly electronegative atom that has a lone pair. (usually another N, O, or F atom in a compound) .

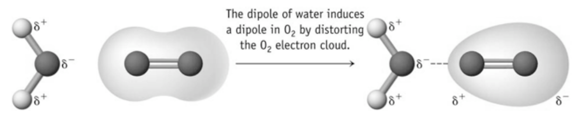
Consequences of H-bonding

- Compounds (like water) have high boiling points, low vapor pressures, and strong cohesive and adhesive forces.
- Water: Surface tension
- Water: Capillary action



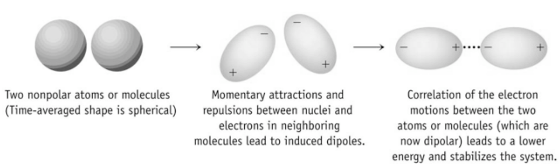
Dipole – induced dipole

- Occurs when a permanent dipole causes a non-polar species to polarize, forming a temporary dipole.
- This is a weak interaction.
- This phenomenon allows non-polar molecular to dissolve slightly in polar solvents (and vice-versa).



Induced dipole – induced dipole: London dispersion forces

- Dispersion forces occur between non-polar molecules.
- These forces occur when a temporary dipole forms by chance in one molecule and induces a dipole in a second.
- This is a weak interaction.



Intermolecular interactions and physical properties

- **Order of Strength:**

  Ion-dipole > Hydrogen Bonds >

  Dipole-Dipole > Dispersion forces (induced dipoles)

- **Effects of Intermolecular forces on Boiling Point:**
  - Molar mass effects
  - Intermolecular interactions

Phase Changes

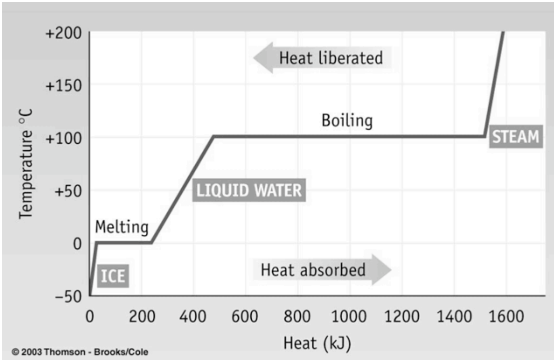
- We can easily relate the heat added to an object and its change in temperature if we know its specific heat and mass: $\mathbf{q = mC_p\Delta T}$
- However, when a compound ***changes state***, there is ***no temperature change***.
- For example, when ice (solid water) melts, it changes from ***solid*** H_2O to ***liquid*** H_2O all at 0.0°C.

Phase Changes

- However, a lot of energy is required to break the intermolecular forces that hold the water molecules in their crystal structure.
- To measure this energy change, we employ the **heat of fusion (ΔH_{fus})** for water – the amount of energy required to melt one mole of ice at 0°C.
- Likewise energy is required to vaporize water at 100°C. The amount of energy required to vaporize one mole of water is called the **heat of vaporization (ΔH_{vap})**:

  $q_{process} = n \cdot \Delta H_{process}$, where n is moles.

Phase Change Diagram (figure 6.10)



Heat-related constants for WATER

Specific Heat Capacity	$^{J}/_{g \cdot C^{\circ}}$
Solid	2.1
Liquid	4.184
Gas	2.0

Phase Changes	$^{kJ}/_{mol}$	$^{J}/_{g}$
ΔH_{fus}	6.01	334
ΔH_{vap}	40.7	2260

Freezing & Condensation

- So far, we have talked only about heat required to melt or vaporize a substance.
- The reverse process has ΔH values with opposite signs:

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

$$\Delta H_{freezing} = -\Delta H_{fusion}$$

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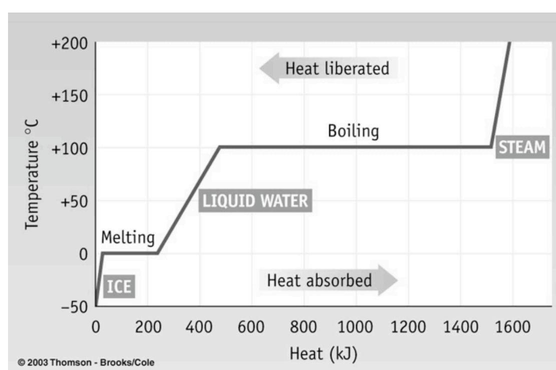

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Phase Changes Examples

1. What is the amount of energy required to vaporize 45.9 g of water at 100°C?

2. What is the energy required to change a 100.0 g ice chunk at –20.0°C to steam at 100.0 °C?

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Calorimetry & Phase Changes

The q terms we discuss here can be used in 1st Law calorimetry problems: $-q_{system} = q_{surroundings}$

3. Seven ice cubes having a combined mass of 185 g are taken from a freezer at -15.0°C and are added to 591 mL (20 fl.oz.) of soda at 19.0 °C in an insulated cup. When thermal equilibrium is reached the solution is at 0.0 °C. Assuming no heat exchange with the cup or the rest of the environment, what mass of ice remains?
(Assume the density and heat capacity of the soda are the same as that of water.)

Phase diagram for water