Chapter 5
Energy and States of Matter

Objectives
- Understand the energetic relationships between states of matter
- Be able to describe states of matter on the macroscopic and particulate levels
- Be able to describe the attractive forces between particles, their relative magnitudes, and how they affect the freezing points and boiling points of substances
- Understand what happens with various phase changes, and how energy is related to the phase changes (exothermic/endothermic, heats of fusion and evaporation)

Energy and States of Matter
- The energy in a substance is reflected in its state of matter – solid, liquid, gas
- The states can be examined on the particulate level or the macroscopic level
Energy and States of matter

- What are those particles?
  - Ionic compound - _______________
    - Held to each other by _______________
  - Covalent compound- _______________
    - Held to each other by:
      - Polar: _______________
      - Polar with O-H, N-H or F-H: _______________
      - Nonpolar

Transitions Between States of Matter

- What must be done physically to transition between states?
  - Solid to liquid:
  - Liquid to gas:
  - Gas to liquid:
  - Liquid to solid:
- The melting and boiling points for substances depend upon the attractive forces between particles
Melting and Boiling Points

- The stronger the forces between particles, the higher the boiling and melting points (for molecules of relatively similar mass) - more energy is required to overcome the interactions

<table>
<thead>
<tr>
<th>Substance</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>1465 °C</td>
</tr>
<tr>
<td>H₂O</td>
<td>100 °C</td>
</tr>
<tr>
<td>HCl</td>
<td>-85.1 °C</td>
</tr>
<tr>
<td>NO</td>
<td>-151.8 °C</td>
</tr>
<tr>
<td>CH₄</td>
<td>-161.6 °C</td>
</tr>
</tbody>
</table>

Melting and Freezing

- Melting point – the temperature at which particles in a solid have gained enough heat to overcome attractive forces between them and spread from the ordered solid to a more random liquid

- Freezing point – the temperature at which enough heat has been removed from a liquid to lower the energy of the particles below that necessary to overcome attractive forces between particles

Melting and Freezing Equilibrium

- At what temperature does water freeze?
- At what temperature does ice melt?
- What is the difference between the ice and the water?
Heat of fusion

- **Heat of fusion** is the energy necessary to separate particles of a solid that has already reached its melting point.
- Heat of fusion does not change the temperature of a substance.
- Heat is first used to raise the temperature of ice to its melting point. If no additional energy is added, the ice will remain solid at 0 °C.

In the reverse process, the heat of fusion is what must be removed to allow the particles of water to “settle down” close together to form solid ice.

Spraying water on orchards before a deep freeze can actually protect the fruit.

Sublimation

- When a solid changes directly to a gas without becoming a liquid, the process is called sublimation
  - Dry ice:
  - Mothballs
  - Deposition -
Boiling and condensation

- When fast moving liquid molecules gain enough energy to leave the surface, evaporation takes place.
- Boiling point – the temperature at which all the particles within a liquid have energy needed to change to a gas; bubbles form throughout the liquid when boiling takes place.
- As vapor molecules lose energy they slow down and attractive forces pull them together: condensation

Evaporation and Condensation

- At what temperature does water vaporize?
- At what temperature does it condense?
- The difference is the heat of vaporization
The heat of vaporization is the energy input necessary to change liquid at its boiling point to vapor.

The heat of vaporization is also the energy that must be removed to change vapor at its boiling point to liquid.

Heats of Fusion and Vaporization

- **Heat of fusion for water:** 80 cal / g
  - Ice at 0°C to water at 0°C, 80 cal / g absorbed
  - Water at 0°C to ice at 0°C, 80 cal / g released

- **Heat of vaporization for water:** 540 cal / g
  - Water at 100 °C to steam at 100 °C
  - Steam at 100 °C to water at 100 °C

How much heat is required to raise the temperature of 100 grams of water from 87°C to 92°C?

Specific heat of water = 1.00 cal / g °C
How much heat is required to raise the temperature 100 grams of water from 97°C to 102°C

- Specific heat of steam = 0.24 cal / g °C

Heat (97 to 100 °C) = \( \frac{1.00 \text{ cal}}{\text{g °C}} \times \frac{100 \text{ g}}{1} \times \frac{3 \text{ °C}}{1} = 300 \text{ cal} \)

Heat (liquid to gas) = \( \frac{540 \text{ cal}}{\text{g}} \times \frac{100 \text{ g}}{1} = 54000 \text{ cal} \)

Heat (100 to 102 °C) = \( \frac{0.24 \text{ cal}}{\text{g °C}} \times \frac{100 \text{ g}}{1} \times \frac{2 \text{ °C}}{1} = 48 \text{ cal} \)

The same change in temperature requires significantly more energy to change between states of matter.

Heating and Cooling Curves

- Endothermic processes absorb (require) heat.
  - Where does the heat come from?
  - The substances at the end of the process have more energy than substances at the beginning.

- Exothermic processes release heat.
  - The substances at the end of the process have less energy than substances at the beginning.

Classifying energy processes
Summary of changes of state

Which involve changes of state?

- Ice melting in your sweet tea?
- Dry ice “disappearing” in an ice cream cart
- Salt dissolved in water.
- Clothes drying on the clothesline.

Energy differences

- Choose which substances are higher in energy.
  - 1 cup of coffee at 70°C or 1 spoonful at 70°C
  - 1 L of water at 50 °C or 1 L water at 90°C
  - 5 g of solid Al at its melting point or 5g of liquid Al at its melting point
Some things to note….

- Freezing and melting points occur at the same temperature for a substance.
- Boiling and condensation points occur at the same temperature for a substance.
- Sublimation and Deposition points occur at the same temperature for a substance.