Heating and Cooling Curves

**Aim:** To determine how energy influences phase changes during heating and cooling.

Phase Changes

All phase changes occur at constant temperature. Therefore average kinetic energy remains constant.

During a phase change, the heat added (PE increases) or released (PE decreases) will allow the molecules to move apart or come together.
### Phase Changes

<table>
<thead>
<tr>
<th>Fusion (melting): solid to a liquid</th>
<th>Solidification (freezing): liquid to a solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling (vaporization): liquid to a gas</td>
<td>Condensation: gas to a liquid</td>
</tr>
<tr>
<td>Sublimation: solid to a gas</td>
<td>Deposition: gas to a solid</td>
</tr>
</tbody>
</table>

#### Endothermic Phase Changes

1. **Melting (fusion):** s to l  
   ![Solid to Liquid](image1.png)  
   Heat absorbed causes the molecules to move farther apart by overcoming the intermolecular forces of attraction.

2. **Boiling (vaporization):** l to g  
   ![Liquid to Gas](image2.png)  

3. **Sublimation:** s to g  
   ![Solid to Gas](image3.png)  

#### Exothermic Phase Changes

4. **Freezing (solidification):** l to s  
   ![Liquid to Solid](image4.png)  
   Heat released allows the molecules to move closer together and the intermolecular forces of attraction become stronger.

5. **Condensation:** g to l  
   ![Gas to Liquid](image5.png)

6. **Deposition:** g to s  
   ![Gas to Solid](image6.png)
Phase Changes and Heating Curves 2016 Notes

AB: phase = solid
Energy Changes: KE increases and particles move faster. PE remains constant.
Formula: \( Q = mc\Delta T \) to calculate the heat absorbed.

BC: phase = solid to liquid, fusion (melting)
Energy Changes: KE remains constant. PE increases and particles move farther apart. (IMF are overcome)
Formula: \( Q = mH_f \) to calc. the heat absorbed.

CD: phase = liquid
Energy Changes: KE increases and particles move faster while PE remains constant.
Formula: \( Q = mc\Delta T \) to calc. the heat absorbed.

DE: phase = liquid to gas, vaporization (boiling)
Energy Changes: KE remains constant while PE increases and particles move farther apart (IMF are overcome).
Formula: \( Q = mH_v \) to calc. the heat absorbed.

EF: phase = gas
Energy Changes: KE increases and particles move faster while PE remains constant.
Formula: \( Q = mc\Delta T \) to calc. the heat absorbed.
During the phase changes of a heating curve the KE remains constant while PE increases (heat is absorbed during heating) to allow the molecules to move farther apart together and IMF are overcome.

During the phase changes of a cooling curve the KE remains constant while PE decreases (heat is lost during cooling) to allow the molecules to move closer together and IMF increases.
Heating and Cooling Curves

- Shows the temperature of each phase change when temperature is constant. (flat line)
- Shows the boiling point and melting point of a substance.
- Can be used to determine the phase of matter at a given temperature.
- Can be used to determine if the substance needs more energy to melt (fusion) or boil (vaporize).

For water --> $H_f = 334 \, \text{J/g}$  $H_v = 2260 \, \text{J/g}$

It takes more heat to vaporize water than to boil because more IMF must be overcome during vaporization than during melting. (more space between the molecules needed to form a gas than a liquid)
1. At what temperature does the substance begin to melt?

2. What temperature does it boil?

3. At which section is the substance a solid? liquid? gas?

4. What sections of the graph have constant kinetic energy?

5. What sections of the graph have constant potential energy?
Practice Problems

5. At which point do a liquid and a solid exist at equilibrium?
   A) sublimation point   C) boiling point
   B) vaporization point   D) melting point

6. As water vapor condenses at 100°C, the potential energy of the molecules
   A) decreases   C) remains the same
   B) increases

7. Which change of phase is endothermic?
   A) \( \text{H}_2\text{O}(s) \rightarrow \text{H}_2\text{O}(g) \)
   B) \( \text{CO}_2(s) \rightarrow \text{CO}_2(l) \)
   C) \( \text{H}_2\text{S}(g) \rightarrow \text{H}_2\text{S}(l) \)
   D) \( \text{NH}_3(l) \rightarrow \text{NH}_3(g) \)