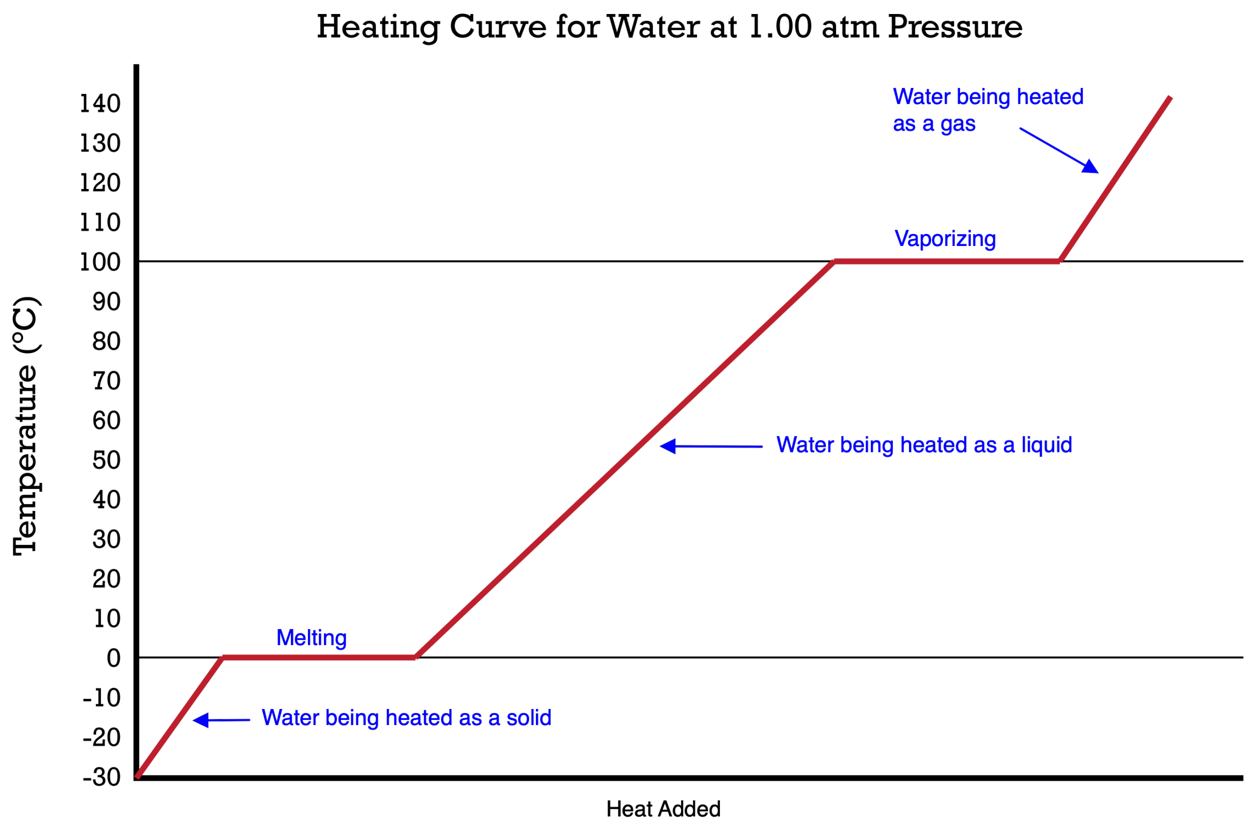
Heating and Cooling Curves

The phase changes that we have discussed can be illustrated in graphs called **heating curves** or **cooling curves**.

Heating Curve

The heating curve for water is shown below. It shows how the temperature of a sample of ice changes as it is heated, gradually transitioning to the liquid and eventually the vapor phase.



An interpretation of each section of the graph is included below:

1. Water being heated as a solid
    - we start with a sample of ice at $-30°C$
    - as we heat the ice, its temperature steadily rises until it reaches $0°C$
    - during this time, the heat energy is being used to increase the *kinetic* energy of the water molecules

2. Melting
    - upon reaching $0°C$, the ice begins to melt
    - while the ice is melting, the solid (ice) and liquid (water) phases coexist
    - during this time, the heat energy is being used to overcome the intermolecular forces between the water molecules (which increases their *potential* energy)

- the temperature of the ice/water mixture will not increase until all of the ice has turned to water
- the temperature at which this plateau occurs is the **melting point**

3. Water being heated as a liquid
   - once all of the ice is melted, the temperature will begin to rise again (assuming we continue to add heat)
   - the temperature of the water will increase smoothly from 0°C to 100°C
   - during this time, the heat energy is being used to increase the *kinetic* energy of the water molecules

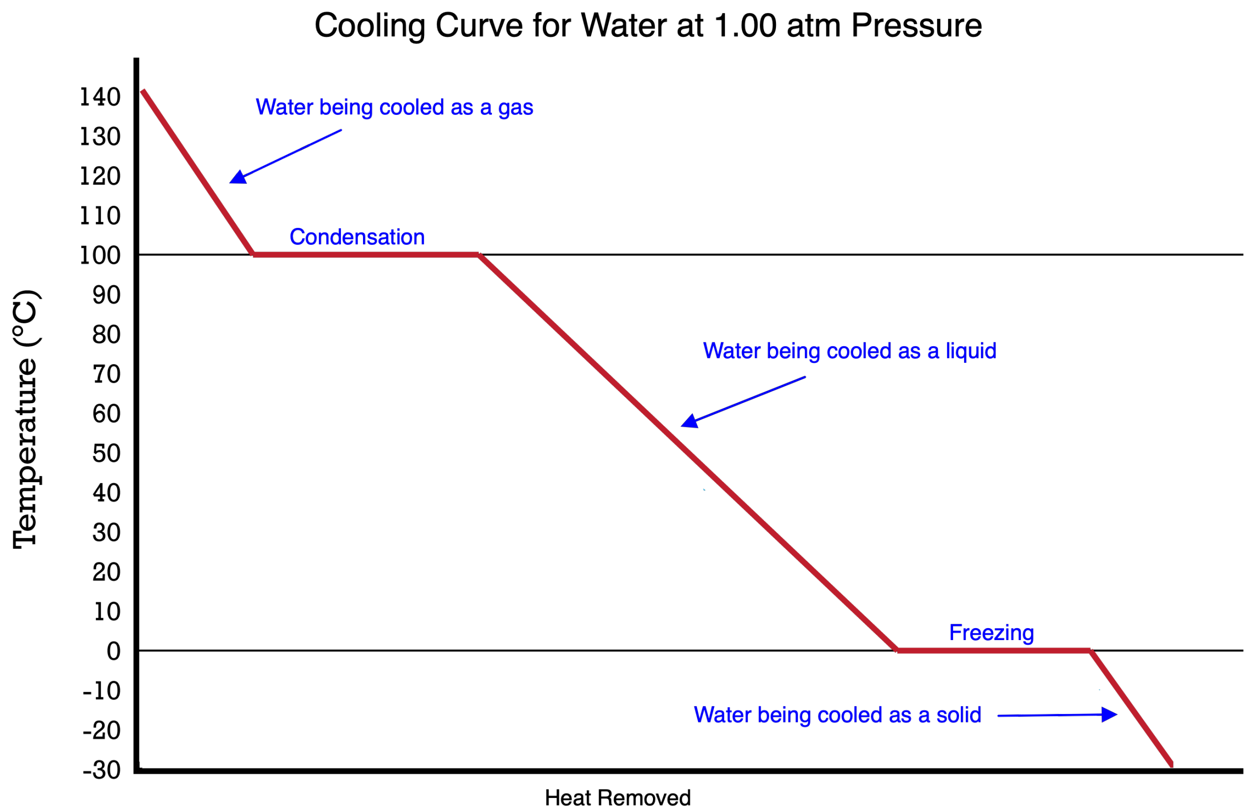
4. Vaporizing
   - upon reaching 100°C, the water begins to boil
   - while the water is boiling, the liquid (water) and gas (water vapor) phases coexist
   - during this time, the heat energy is being used to overcome the intermolecular forces between the water molecules (which increases their *potential* energy)
   - the temperature of the liquid/vapor mixture will not increase until all of the water has turned to vapor
   - the temperature at which this plateau occurs is the **boiling point**

5. Water being heated as a gas
   - once all of the water has vaporized, the temperature will begin to rise again (assuming we continue to add heat)

A heating curve for any other substance would look very similar, except that the melting point and boiling point would occur at different temperatures than they do for water.

Cooling Curve

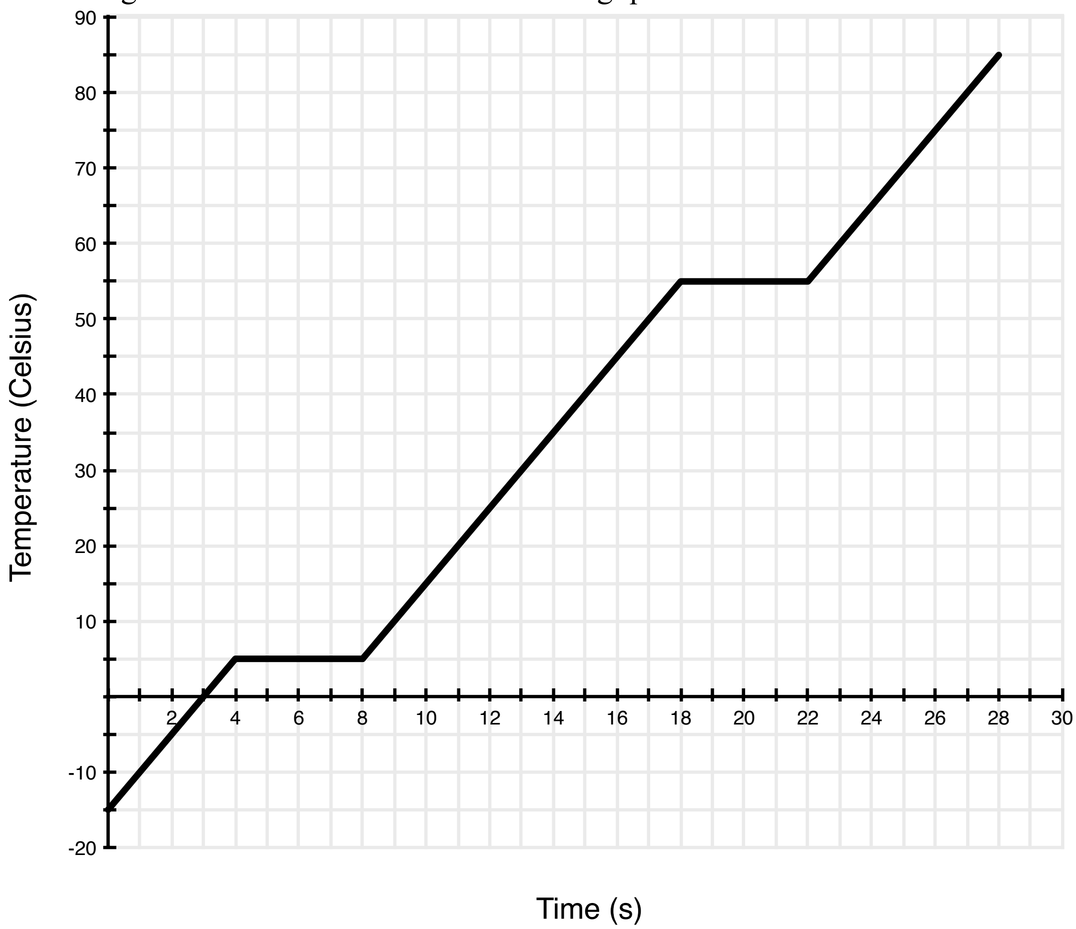
The cooling curve for water is shown below. It shows how the temperature of a sample of water vapor changes as it is cooled, gradually transitioning to the liquid and eventually the solid phase.



An interpretation of this graph would be very similar to the interpretation of the heating curve, only in reverse.

Worksheet

1. Use the heating curve below to answer the following questions.



   a) During what time interval would the substance have a definite shape and volume?
   b) During what time interval would the substance have a definite volume but no definite shape?
   c) During what time interval would the substance have no definite shape or volume?
   d) During what time interval is the substance in both the solid and liquid phase?
   e) During what time interval is the substance in both the liquid and vapor phase?
   f) What is the melting point of the substance?
   g) What is the boiling point of the substance?
   h) During which time interval(s) is the kinetic energy of the substance increasing?
   i) During which time interval(s) is the potential energy of the substance increasing?

2. A substance, X, has a melting point of $-15°C$ and a boiling point of $75°C$. Sketch a heating curve for substance X starting at $-50°C$.