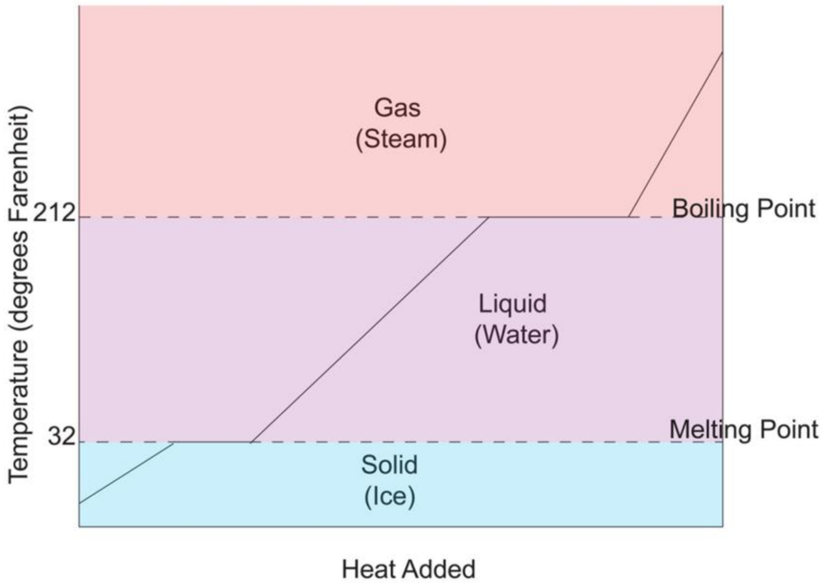
This experiment aims to explain the concepts of States of Matter, Heat, and Changes in Matter and is applicable to **Standards 2.4 and 3.4.** The successful student will be able to explain the three common states of matter and will understand the relationship between these three states.

Background

All materials can exist in three common physical states – solid, liquid and gas (**Standard 2.4**). This is shown in the image below for the common example of water.



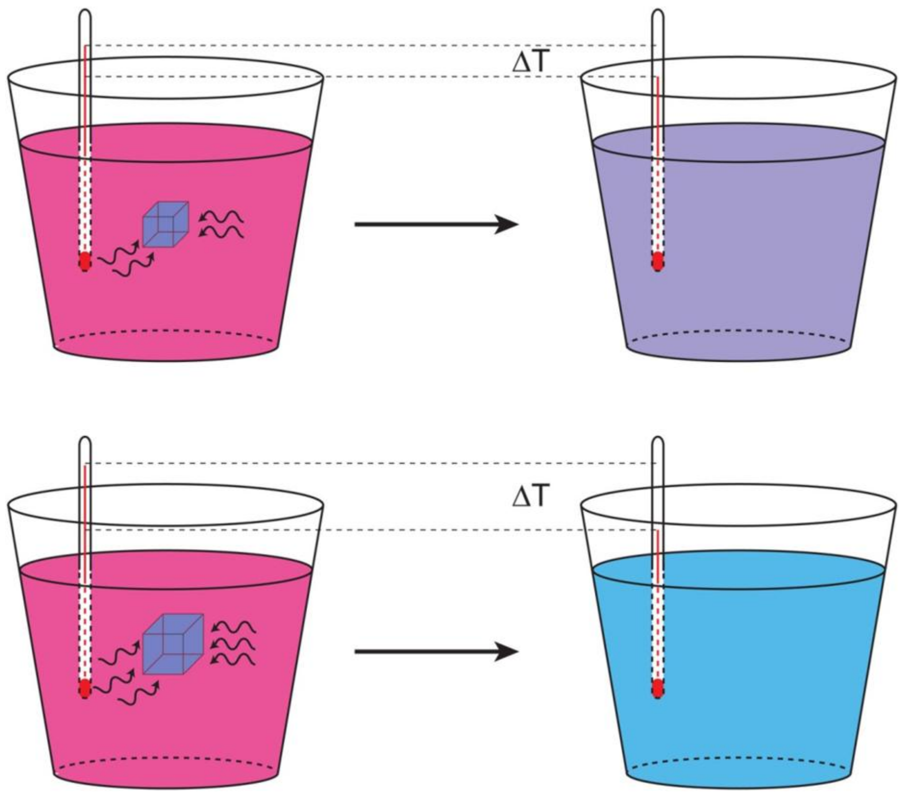
A transition from one physical state to another is always characterized by a transfer of energy. For example, you must add energy in the form of heat to make water boil or melt ice. This concept is perfectly exemplified when ice is added to a cup of water or tea. The water molecules in the liquid phase have more energy than the molecules in the solid phase. The reason that the ice melts is that some of the energy in the water is transferred to the ice – this provides the heat necessary for the transition from the solid to liquid phase.

In general, this is the reason that objects feel hot or cold when they are touched. If you grab an ice cube, the molecules in your fingers have more energy than the ice, so your fingers lose energy and you feel the cold sensation. The opposite is true when you grab a hot curling iron. The metal has more energy than your fingers, so some of that energy is transferred to your fingers and you feel a 'hot' sensation. Both of these examples rely on the concepts of *thermal equilibrium* and *conservation of energy*.

The principle of thermal equilibrium simply states that two objects of differing temperatures that come into contact will eventually become the same temperature. As suggested above, this happens because some of the energy in the hot object is transferred to the cold object.

The law of **Conservation of Energy (Standard 6.5)** tells us that the energy passed from the hot object must be exactly equal to the amount of energy transferred to the cold object. This idea can be directly observed by dropping a cold object into a warm liquid and observing the change in temperature. As represented by the image below, the magnitude of the temperature change (ΔT) will be dependent on the size of the cold object added.

We'll explore this idea by using a very simple instrument called a calorimeter to monitor the change in temperature. A calorimeter is a tool to measure changes in heat when two or more compounds are mixed together. There are very sophisticated calorimeters capable of measuring very small changes in temperature that are used in modern research. However, the instrument that we will use is the simplest form that can be reliably designed. Styrofoam cups will be used to as the water reservoir due to their **insulating** ability which limits the amount of heat that is transferred out of the calorimeter – this will make the measurements more accurate.



Varying the size or number of ice cubes that are dropped in the water will have a very big influence on how cold the water gets. This is due to a very simple mathematical relationship described by equation 1

$$E = mC\Delta T \quad (1)$$

where *E* is the total amount of energy that is stored in the ice cube (think of this as the potential to chill the water), *m* is the mass of the ice cube, ΔT is the change in temperature that will occur when the ice and liquid water are mixed, and *C* is known as the specific heat (or heat capacity). While this is well beyond the scope of this experiment for elementary school students, it is quite easy to see how the size of the ice cube will influence the temperature change.

Test your understanding*:*

Why will a Styrofoam cup work better than a paper or metal cup?

What is the minimum temperature that liquid water can be?

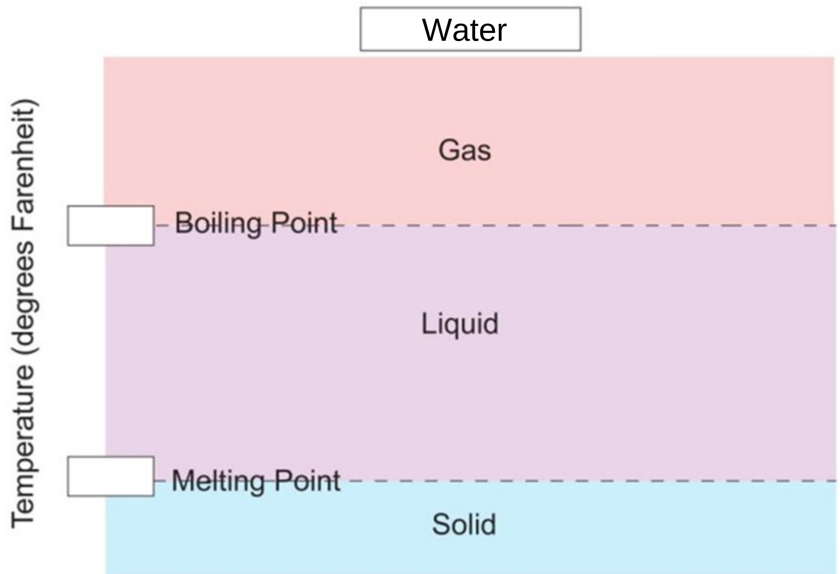
What is the maximum temperature that liquid water can reach?

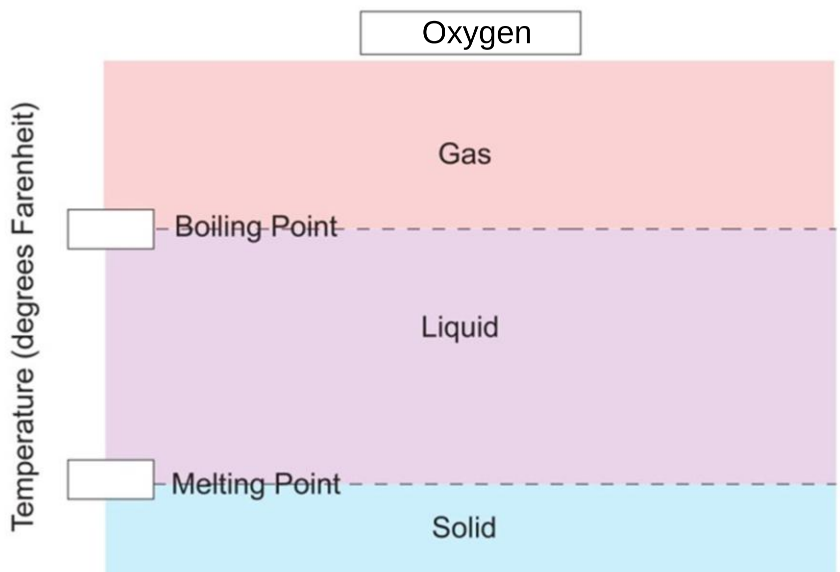
Using what you know about each of these compounds, predict whether it is a solid, liquid or gas at room temperature (70 ºF)?

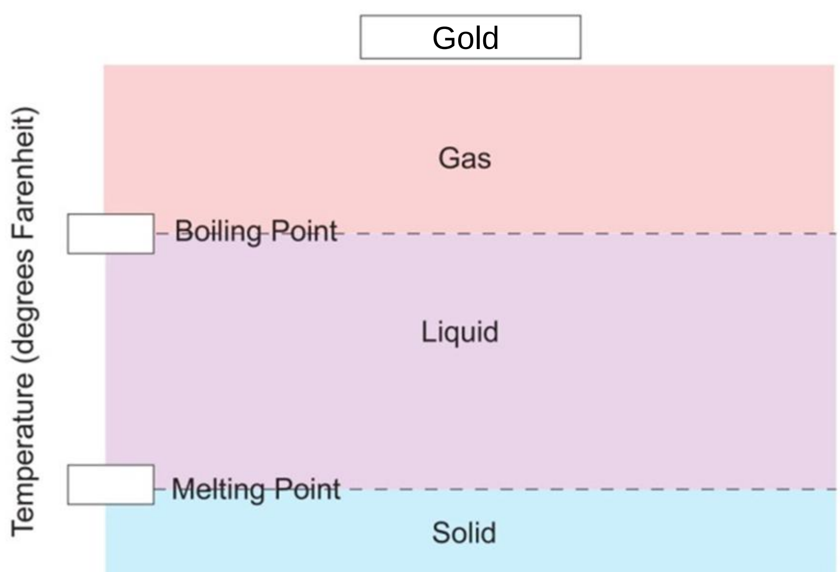
- *Water*
- *Oxygen*
- *Gold*

The table below gives the melting and boiling temperatures for each of the three compounds. Using this information, fill in the empty boxes in the images below. Put a star on the y-axis where room temperature would be. Circle the phase that this element is found at room temperature.

Compound	***Melting Temperature (ºF)***	***Boiling Temperature (ºF)***
Water	*32*	*212*
Oxygen	*-362*	*-297*
Gold	*1947*	*5173*


Water
Gas
Boiling Point
Liquid
Melting Point
Solid
Temperature (degrees Farenheit)


Oxygen
Gas
Boiling Point
Liquid
Melting Point
Solid
Temperature (degrees Farenheit)


Gold
Gas
Boiling Point
Liquid
Melting Point
Solid
Temperature (degrees Farenheit)

Experimental Preparation

Materials:

- Ice
- Water (tap water will suffice, but distilled is better)
    - Tip – the water should be pre-equilibrated at room temperature.
- Thermometer (needs to be readable in the 0-100 ºC or 32-212 ºF range)
- Styrofoam cup (smaller volumes are better since only 50mL will be used)
- Graduated Cylinder – or way to measure similar volumes of water

Procedure:

1. Add ~100 mL of water to a Styrofoam cup.
2. Measure the temperature of the water.
3. Add the indicated number of ice cubes to the water. Wait for the ice to melt (this may take quite a while for the 10 piece experiment – you may consider allowing just 5-10 minutes for each data point or excluding the last experiment.
4. Measure the temperature after the ice has melted.
5. Calculate the temperature change

    Change = Final Temperature – Initial Temperature
6. Make a graph of Number of Ice Pieces vs. Change in temperature

Data

Number of Ice pieces	Initial Temperature	Final Temperature	Change in Temperature
0			
2			
5			
10			

Additional questions:

How could we make the water boil?

At what temperature would the water boil?

What would happen if you held an ice cube over a steam vent?