Demonstrating an inversion with boiling water and ice

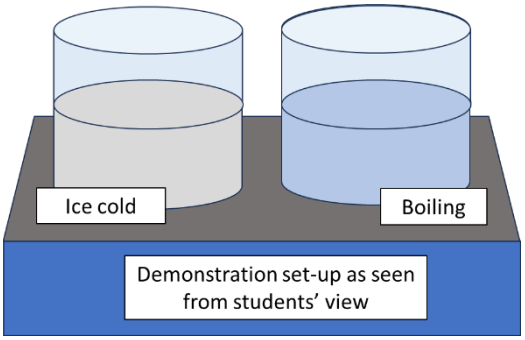
Find these in the trunk or your lab supplies:

- Two 1-qt freezer contains or two 500-ml beakers
- Digital thermometer with thermocouple wire. Make sure the thermometer's battery works. Have a spare on hand.

On the day before the activity, fill one of the containers half full with water and freeze it. If you forget, use ice cubes.

On the day of the activity, have boiling water ready to fill the other container half-way. Keep it hot until you need it.

Set up your lab bench or demonstration table with the container of ice on the right side (facing the class) and the empty container on the left. Make two signs ("Ice cold" and "Boiling"). Place them next to the appropriate containers.



Write the following table on the board or project it:

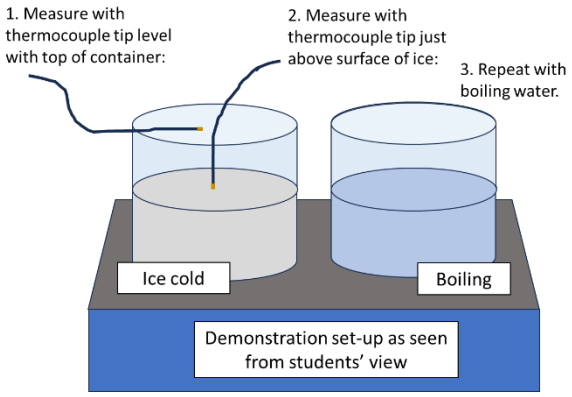
	Ice cold	Boiling
Temperature °C, level with top of container		
Temperature °C, inside container, 0.1 cm above ice or water		
Is air right above ice/water warmer or colder than air above?		
Compare/contrast the movement of air in the containers:		
Is the air in the container stable or unstable?		
Is an inversion present?		

Procedures:

1. Explain: To understand how smoke moves around and how it can get stuck in valley bottoms, making it hard for us to see and breathe, we have to understand the daily movement of air. Every day, sunlight reaches the earth's surface, heats it up, and heats the surface air as well. Every night, the earth cools off because the sun isn't heating it anymore, and the surface air cools off too. We're going to investigate how air behaves – how it moves around – above hot and cold surfaces.

2. Get 3 students to help with the demonstration and begin:

a. Have one student turn on the digital thermometer and hold its display up so the class can see it.
b. Have the class call out the temperature (degrees C). Have them agree on a temperature or – if it is varying and hard to pin down, a range of temperatures. Explain that this is how they'll describe the temperatures in the demonstration.
c. In the "Ice cold" container, have students measure and record the temperature or (if it varies a lot) the range of temperatures at these 2 locations:
   - Level with top of container, over its center
   - Inside container, about 1 mm above surface of ice (not touching ice). If the thermocouple touches the ice, you'll know you'll know right away because the temperature will change very fast. Just dry it off and try again.



d. In the "Boiling" container, do the same thing.

3. After the measurements are done, use discussion to complete the table. See the example below.

   a. For each container, is the temperature 1 mm near the ice/water "warmer" or "colder" than the temperature above, at the top of the container?

   b. How would you compare what the air is doing in the two containers? Use pairs of "compare/contrast" words, such as *quiet* vs. *wild*, *still* vs. *busy*, *unmoving* vs. *moving, or peaceful vs. turbulent*.

   c. For each container, would you call the air above the ice/water surface *stable* or *unstable*?

4. Explain: If the air is stable, there is an *inversion* present. That is, the usual pattern of warm air on the bottom and cooler air on top is now upside-down, trapping the cold air at the bottom. That's how smoke can get stuck and make the air murky and hard to breathe. The same thing can happen with dust and automobile exhaust on winter days.

   Here is an example of the information that should be in the table when you're done:

	Ice	Boiling water
°C, level with top of container	18-19	22-46
°C, inside container, 1 mm above ice or water	7	66-93
Is the air right above ice/water surface warmer or colder than air above?	colder	warmer
Describe the movement of the air right above the ice/water surface:	still dull peaceful	wild crazy turbulent

	etc.	etc.
Air right above the water: stable or unstable?	stable	unstable
Inversion present?	yes	no

5. Ask: What conditions might keep the surface air from rising and thus create an inversion? Clouds may block the incoming sunlight. In winter, the ground may be covered with snow that reflects sunlight instead of absorbing it. In summer, the smoke from a fire may be too dense to let sunlight through.

6. Review and summarize: Air heated by the earth's surface rises and is constantly replaced by cool air flowing down from higher elevations. These forces keep the air in motion, so we call the atmosphere *unstable*. If the earth's surface is too cold to heat the air on the ground, the dense valley-bottom air cannot rise; it is trapped. Then we call the atmosphere *stable*, because air will not begin moving until the surface air warms up or is disturbed by wind. We call this condition an *inversion*, because the usual temperature gradient (warm below, cold above) is upside-down.