EXPANSION OF WATER

OVERVIEW

Students will measure the rate at which water expands when heated from room temperature to near boiling. An empty wine bottle (or other suitably shaped beaker or bottle) partially filled with water will readily show a large height increase in the neck of the bottle. This serves as a demonstration of how oceans expand when heated, for example as a result of *global warming*.

CONCEPTS

- Solids, liquids and gases expand when heated.
- Water expands about four percent when heated from room temperature to its boiling point.
- The ocean will expand when heated.

MATERIALS

- Empty 750 milliliter bottles (e.g., a clear wine bottle) or beaker with a thin neck
- 0 - 100°C thermometers
- Gas burners with stands or electric hot plates
- Metric rulers
- Six-inch cooking pans (or pots)
- String or emery boards

PREPARATION

Depending on what is available, heating the water can be done at school by using Bunsen burners, a hot plate, or a propane camp unit. At home, a kitchen stove is suitable. Place the bottle or beaker in a cooking pan with water to reduce the possibility of breaking the bottle. Use pyrex instead of a glass bottle if you have a suitable container with a thin neck (such as pyrex Florence flasks). A thin neck will allow ease of measuring changes, because the height of the water will increase more for an equivalent change in volume. In any case, use great care around the bottle, wearing protective eyewear if possible. The thermometer can be suspended in the heated water using string or an emery board with a small hole punched through it. Test a method for suspending the thermometer before doing the activity in class. For safety, do not let the water reach boiling temperature (100°C).

PROCEDURE

Engagement

Small changes in Earth's global average temperature can produce dramatic changes in climate (*Climate - Process and Change*). Scientists are trying to determine how much Earth's mean temperature is changing. One way to do this is to monitor sea level. Warming results in higher sea levels, which may strongly affect the population who live near the ocean. There is geologic evidence for very large variations in Earth's sea level in the past. There are two main causes for these sea level changes: (1) thermal expansion or contraction of the existing ocean water, and (2) changing volume of water due to the melting or freezing of polar ice caps and glaciers. Changes in the climate affect both of these.

Over the past hundred years, average sea level has risen 15 cm (6 in) during the same period that

average global temperature has increased about 0.5°C (0.9°F). Some computer models predict that, over the next hundred years, the present carbon dioxide level in the atmosphere (about 0.032%) could double; this would increase ocean water temperatures by 3°C (5.4°F). Using the 15 cm/0.5°C above, this would cause a sea level rise of about one meter (3.3 ft).

Activity

1. Mark the point on the bottle that is 7 cm from the top. Optionally, measure the inside and outside diameters of the bottle at the top and at 7 cm below the top to determine the dimensions. For example, for a sample 750 ml wine bottle, the measured top and 7 cm position outside diameters were 2.4 cm and 3.0 cm respectively. The corresponding inside diameters were 1.8 cm and 2.4 cm (assuming constant thickness).
2. Fill the 750-ml bottle with water to just below the bottom of the neck. Ice can be used to bring the temperature down to 20°C if desired.
3. Support the thermometer in the bottle so that the bulb is well below the neck in the main body of water. Use either string or something similar to an emory board placed horizontally on the bottle top with the thermometer suspended through it.
4. Add or pour out water so that with the thermometer in the bottle, the water level is 7 cm below the top, as measured with the ruler held vertically.
5. Fill the cooking pan about two-thirds full of water and place on the heat source.
6. Center the bottle in the pan. The water level in the pan should be at least three cm below the top.
7. Heat the water to at least 80°C while recording the water level every 5° or 10°C in Table 1. To prevent the water from spilling, turn off the heat source if the water in the bottle reaches to within one cm of the top.
8. Graph height versus temperature and the change in height versus temperature. Does the height change more or less rapidly at higher water temperatures?

Table 1

t (°C)	h (cm)	Δh (cm)
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		

t = measured temperature of the water in the bottle

h = the height of the water in the bottle measured *downward* from the top (top = 0)

Δh = the change in height of the water between fixed temperatures (e.g., every 5°C)

Explanation

Most materials expand on heating, although some contract over limited ranges of temperature. On average, liquids expand about ten times as much as solids, and gases expand much, much more than liquids. The correction for the expansion of the solid bottle was not included here because it will be very small compared to the expansion of the water. Note that the expansion for water is much greater near its

boiling point than near room temperature.

When oceans heat up, they expand as well, causing a rise in sea level. Such variations in ocean water temperature, along with changes in ocean water volume from the melting and freezing of water in ice caps, has caused Earth's sea level to rise and fall tens of meters over geologic time. Such changes are likely to occur in the future as well.

What you constructed in this activity was basically a thermometer. If you made sure to carefully *calibrate* the level of expansion versus temperature while performing this experiment and re-ran the experiment with the same equipment, you could use your original data to determine water temperature based on its height in the neck of the bottle. However, water is not very suitable for use in a thermometer for many reasons: its amount of expansion changes greatly with temperature range, it evaporates easily, and it does not expand as much as some other liquids. Most thermometers use mercury because it expands quite a lot, and does so uniformly over a very large range of temperatures. (Interestingly, the first thermometer constructed did, in fact, use water.)

Extension

Calculate the volume change of the water that corresponds to the measured changes in height. This will require a good knowledge of the inner diameter of the bottle and its variations. For reference, the expected volume change from 20°C to 90°C is approximately 3.4%.

You may wish to investigate the expansion properties of other liquids like mercury and alcohol, both used in thermometers.

There are many examples of solids that expand with temperature, such as concrete dividers in sidewalks and bridges. The Golden Gate bridge is about 0.9 meters (3 feet) longer in summer than in winter, so room is left on the roadway for expansion to prevent buckling. Can you students think of other examples of volume changes in solid materials that are temperature dependent? Have they experienced changes in the way mechanical devices work during different seasons? Is temperature the only factor that may be affecting the performance of these devices?

Links to Related CD Activities, Images, and Movies

Activity *Making a Greenhouse*

Vocabulary

global warming *calibrate (calibration)*

Source

San Juan Institute.