surrounding it will be slightly warmer. Eventually, both the can of fruit juice and the water will be at the same temperature. That temperature will not change as long as conditions remain unchanged in the beaker. Another way of expressing this is to say that the water and can of juice are in **thermal equilibrium** with each other.

thermal equilibrium

the state in which two bodies in physical contact with each other have identical temperatures

Thermal equilibrium is the basis for measuring temperature with thermometers. By placing a thermometer in contact with an object and waiting until the column of liquid in the thermometer stops rising or falling, you can find the temperature of the object. The reason is that the thermometer is in thermal equilibrium with the object. Just as in the case of the can of fruit juice in the cold water, the temperature of any two objects in thermal equilibrium always lies between their initial temperatures.

Matter expands as its temperature increases

Increasing the temperature of a gas at constant pressure causes the volume of the gas to increase. This increase occurs not only for gases but also for liquids and solids. In general, if the temperature of a substance increases, so does its volume. This phenomenon is known as *thermal expansion*.

You may have noticed that the concrete roadway segments of a bridge are separated by gaps. This is necessary because concrete expands with increasing temperature. Without these gaps, thermal expansion would cause the segments to push against each other, and they would eventually buckle and break apart.

Different substances undergo different amounts of expansion for a given temperature change. The thermal expansion characteristics of a material are indicated by a quantity called the *coefficient of volume expansion*. Gases have the largest values for this coefficient. Liquids have much smaller values.

In general, the volume of a liquid tends to decrease with decreasing temperature. But, the volume of water increases with decreasing temperature in the range between 0°C and 4°C. Also, as the water freezes, it forms a crystal that has more empty space between the molecules than does liquid water. This explains why ice floats in liquid water. It also explains why a pond freezes from the top down instead of from the bottom up. If this did not happen, fish would likely not survive in freezing temperatures.

Solids typically have the smallest coefficient of volume expansion values. For this reason, liquids in solid containers expand more than the container. This property allows some liquids to be used to measure changes in temperature.

MEASURING TEMPERATURE

In order for a device to be used as a thermometer, it must make use of a change in some physical property that corresponds to changing temperature, such as the volume of a gas or liquid, or the pressure of a gas at constant volume. The most common thermometers use a glass tube containing a thin column of mer-

Why it Matters

Conceptual Challenge

1. Hot Chocolate

If two cups of hot chocolate, one at 50°C and the other at 60°C, are poured together in a large container, will the final temperature of the double batch be

a. less than 50°C?
b. between 50°C and 60°C?
c. greater than 60°C?

Explain your answer.

2. Hot and Cold Liquids

A cup of hot tea is poured from a teapot, and a swimming pool is filled with cold water. Which one has a higher total internal energy? Which has a higher average kinetic energy? Explain.