cury, colored alcohol, or colored mineral spirits. When the thermometer is heated, the volume of the liquid expands. (The cross-sectional area of the tube remains nearly constant during temperature changes.) The change in length of the liquid column is proportional to the temperature change, as shown in **Figure 3.**

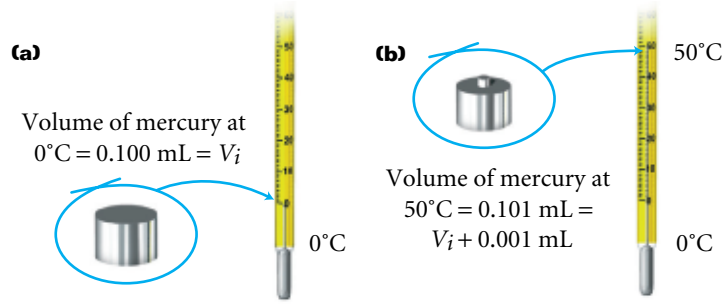

Figure 3
The volume of mercury in this thermometer increases slightly when the mercury's temperature increases from 0°C **(a)** to 50°C **(b)**.

Calibrating thermometers requires fixed temperatures

A thermometer must be more than an unmarked, thin glass tube of liquid; the length of the liquid column at different temperatures must be known. One reference point is etched on the tube and refers to when the thermometer is in thermal equilibrium with a mixture of water and ice at one atmosphere of pressure. This temperature is called the *ice point* or *melting point* of water and is defined as zero degrees Celsius, or 0°C. A second reference mark is made at the point when the thermometer is in thermal equilibrium with a mixture of steam and water at one atmosphere of pressure. This temperature is called the *steam point* or *boiling point* of water and is defined as 100°C.

A temperature scale can be made by dividing the distance between the reference marks into equally spaced units, called *degrees*. This process is based on the assumption that the expansion of the mercury is linear (proportional to the temperature difference), which is a very good approximation.

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Temperature units depend on the scale used

The temperature scales most widely used today are the Fahrenheit, Celsius, and Kelvin scales. The Fahrenheit scale is commonly used in the United States. The Celsius scale is used in countries that have adopted the metric system and by the scientific community worldwide. Celsius and Fahrenheit temperature measurements can be converted to each other using this equation.

CELSIUS-FAHRENHEIT TEMPERATURE CONVERSION

$$T_F = \frac{9}{5} T_C + 32.0$$

$$\text{Fahrenheit temperature} = \left(\frac{9}{5} \times \text{Celsius temperature}\right) + 32.0$$

The number 32.0 in the equation indicates the difference between the ice point value in each scale. The point at which water freezes is 0.0 degrees on the Celsius scale and 32.0 degrees on the Fahrenheit scale.

Temperature values in the Celsius and Fahrenheit scales can have positive, negative, or zero values. But because the kinetic energy of the atoms in a substance must be positive, the absolute temperature that is proportional to that energy should be positive also. A temperature scale with only positive values is

Did you know?

As a thermometer comes into thermal equilibrium with an object, the object's temperature changes slightly. In most cases the object is so massive compared with the thermometer that the object's temperature change is insignificant.