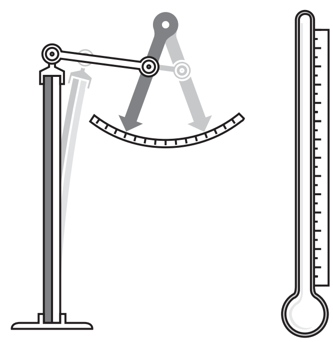
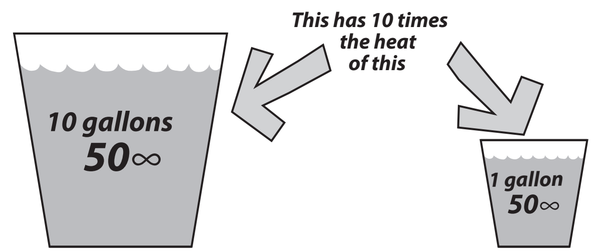
Measuring Temperature



Temperature is measured by the movement of a bimetal element or by the expansion of the liquid metal mercury.

Quantities: Heat and Material



If two different amounts of the same material have the same temperature, the heat content in each is directly related to the mass of the material.

Temperature and Heat

Temperature is a measure of how fast the molecules in a substance are moving or vibrating. Temperature is the average kinetic energy or motion of molecules. Molecules in a solid are stationary, but they vibrate faster and faster as heat is added, raising the temperature.

Heat flows because of a difference in temperature between two places. Heat is measured in *British thermal units (BTU)*, which is the amount of heat required to raise a pound of water's temperature 1°F. A BTU is approximately the amount of heat released by burning one wooden kitchen match. The number of BTUs of heat that a pound of any material absorbs or releases for each degree of temperature change is called its *specific heat*. It is measured in BTUs per pound per degree Fahrenheit (BTU/lb./°F). Water has a specific heat of 1 BTU/lb./°F. It takes only 0.2 BTU to raise a pound of aluminum 1°F, so aluminum has a specific heat of 0.2 BTU/lb./°F. If we add one BTU to a pound of aluminum, it will get 5°F warmer.

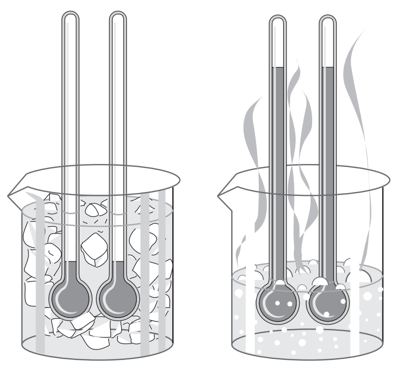
The temperature of a given weight of material tells us how much energy that material contains, which is called *enthalpy*.

Sensible and Latent Heat

The relationship between water's temperature and its heat content is predictable—add a BTU to a pound of water, and by definition, it gets one Fahrenheit degree warmer. Add 150 BTUs to a pound of 50°F water, and its temperature increases 150°F to the temperature of 200°F. This *sensible* relationship ends at 212°F — water's boiling point. With continued heating, the pound of water remains at 212°F, while it absorbs 970 BTUs during its complete evaporation into steam — six times the heat it absorbed going from 50°F to 212°F.

This unexpected or hidden heat, which is released or absorbed as a substance changes form, is called *latent heat*. Our pound of liquid water vaporized when we added 970 BTUs, which is called the *latent heat of evaporation* for water. If we could catch all the steam and recondense it, the 970 BTUs would be released again. This is the principle of steam heating.

Boiling and Freezing Points



The boiling point and freezing point of water are important to calibrating thermometers because these two states are easy to recognize and duplicate. Freezing point: 32°F or 0°C; boiling point: 212°F or 100°C.

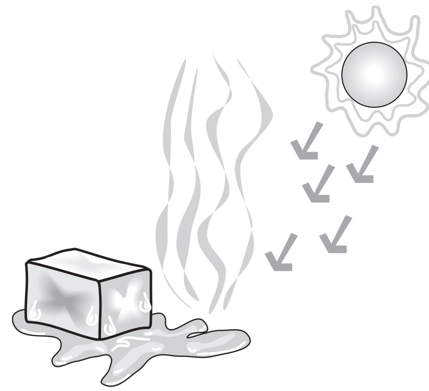
Our pound of water would go through a similar metamorphosis if we were to cool it: the water would lose 1°F for every BTU removed until reaching its freezing point, 32°F. We would then have to remove 144 BTUs — water's *latent heat of fusion* — to turn the pound of water into a block of ice. Conversely, it would take 144 BTUs of heat to melt the pound of ice again.

Steam-heating systems, air conditioners, and refrigerators use latent heat to carry energy from one place to another. In steam heating systems, water is vaporized at a boiler and condensed back to a liquid in radiators. In an air conditioner, a special fluid called a refrigerant vaporizes at the evaporator, absorbing heat from inside the home in the process. The hot gas is then piped outdoors to a condenser, where it *condenses* back to a liquid, releasing its latent heat into the outdoor air.

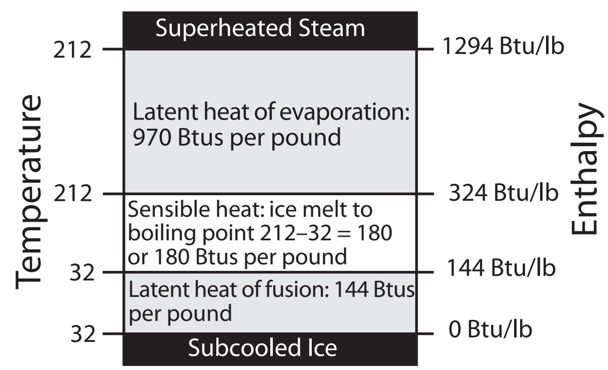
Heat and Work

The American system of measurement has many ways of describing energy — the BTU for heat and the foot-pound for work being two of the most common. If you lift a one-pound weight one foot off the floor, you have done one *foot-pound* of work.

Latent Heat



Latent heat is the heat absorbed or released when a material changes phase between a solid and a liquid or between a liquid and a gas.



At the phase changes, temperature remains constant while enthalpy changes dramatically. Although often considered zero BTUs/lb. enthalpy, ice still has some energy content.

To prove that heat and work are equivalent, a British physicist, James Joule, used mechanical energy (or work) to stir water. He found that for every 778 foot-pounds of work he performed stirring one pound of water, the pound of water absorbed 1 BTU. Joule determined this by measuring temperature change of stirred water in an insulated tank. Now we know that 778 foot-pounds is equivalent to 1 BTU. This was an essential piece of knowledge for the industrial revolution.

The *joule,* an international energy unit, describes both work and heat. A million BTUs (MMBTU) approximately equals a gigajoule (billion joules).