# What Is Temperature, And How Does It Differ From Heat?

Temperature is a measure of the *average* kinetic energy of all the molecules in a substance. Because it is an average of the kinetic energy of all the molecules, the temperature of a substance does not depend on the total number of molecules in a substance. On the other hand, heat is a function of the number of molecules in a substance, so there is a difference between heat and temperature. Heat is a form of energy, while temperature is a measure of the degree of hotness of a substance, and is measured by a thermometer.

Kinetic energy (K) is equal to ½ of the mass (m) of a molecule (or a body of some type) times the square of its velocity (v). $K = ½ mv^2$. Therefore the kinetic energy of a molecule is dependent on both the mass of the molecule and its velocity. Since velocity is squared, then the kinetic energy of a molecule will be much more dependent on the velocity of the molecule (simply because $v^2$ will be a much larger number than m). In this sense, temperature can be said to be a measure of the average speed at which all of the molecules in a substance are traveling. This is how temperature is often defined in simple terms.

Here is an example to distinguish heat and temperature. A small red-hot tack is much hotter than a large bowl of warm water. But the warm water contains more heat than the tack. The red-hot tack is at a higher temperature than the warm water, because temperature is a measure of the degree of hotness of a substance as read on a thermometer. Heat is a form of energy. When a substance is hot its molecules move more rapidly than when it is cold. The heat of a substance is a measure of the total of all the energy of motion of all of its molecules. Its temperature is a measure of the average energy of motion of its molecules. Since there are many more molecules in the bowl of water than in a small tack (the water weighs much more than a small tack), then the water contains more energy in all of its moving molecules. But the tack is at a higher temperature because the average energy of all of its molecules is greater than that of the water.

Distinguishing between heat and temperature is important in cooking science. The cook's at America's Test Kitchen devised a simple test to demonstrate the difference. They carefully heated containers of equal volumes of olive oil and water to 165° F (74° C) in a sous vide water bath, then placed a raw egg into each one. The water turned the egg white cloudy very quickly, indicating the proteins were denaturing and coagulating. The egg in the olive oil looked like nothing had happened-the egg white was still transparent. The experiment is reproduced in the photos below showing a raw egg added to pans of olive oil and water heated to 165° F.

Olive oil @ 165° F

Water @ 165° F

The reason that water cooks the egg faster than olive oil is because it takes more energy to heat water to 165° F than it does olive oil. The amount of energy required to raise the temperature of a substance is called the *heat capacity* of that substance, and each substance has a different heat capacity. The heat capacity of water is about 2.1 times greater than olive oil. All that extra energy required to raise the temperature of water to 165° F is available to cook the food faster. To learn more about heat capacity and cooking food read the next science note on “Thomas Keller and the Science of Butter-Poached Lobster”, as well as “Why Foods Cook Slower in Oil”, *Cook’s Illustrated*, March & April 2012