

Temperature is proportional to the kinetic energy of atoms and molecules

The **temperature** of a substance is proportional to the average kinetic energy of particles in the substance. A substance's temperature increases as a direct result of added energy being distributed among the particles of the substance, as shown in **Figure 2**.

A *monatomic* gas contains only one type of atom. For a monatomic gas, temperature can be understood in terms of the translational kinetic energy of the atoms in the gas. For other kinds of substances, molecules can rotate or vibrate, so other types of energy are also present, as shown in **Table 1**.

The energies associated with atomic motion are referred to as **internal energy**, which is proportional to the substance's temperature (assuming no phase change). For an ideal gas, the internal energy depends only on the temperature of the gas. (See "Properties of Gases" in **Appendix J: Advanced Topics** to learn about ideal gases.) For nonideal gases, as well as for liquids and solids, other properties contribute to the internal energy. The symbol U stands for internal energy, and ΔU stands for a change in internal energy.

Temperature is meaningful only when it is stable

Imagine a can of warm fruit juice immersed in a large beaker of cold water. After about 15 minutes, the can of fruit juice will be cooler and the water

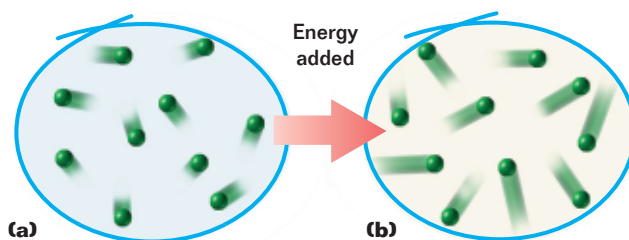


Figure 2

The low average kinetic energy of the particles **(a)**, and thus the temperature of the gas, increases when energy is added to the gas **(b)**.

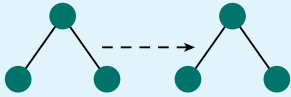

temperature

a measure of the average kinetic energy of the particles in a substance

internal energy

the energy of a substance due to both the random motions of its particles and to the potential energy that results from the distances and alignments between the particles

Table 1 Examples of Different Forms of Energy

Form of energy	Macroscopic examples	Microscopic examples	Energy type
Translational	airplane in flight, roller coaster at bottom of rise	CO ₂ molecule in linear motion	kinetic energy 
Rotational	spinning top	CO ₂ molecule spinning about its center of mass	kinetic energy 
Vibrational	plucked guitar string	bending and stretching of bonds between atoms in a CO ₂ molecule	kinetic and potential energy 