The principle of energy conservation that takes into account a system's internal energy as well as work and heat is called the *first law of thermodynamics.*

Imagine that the isothermally expanding toy balloon in the previous section is squeezed rapidly. The process is no longer isothermal. Instead, it is a combination of two processes. On the one hand, work (W) is done on the system. The balloon and the air inside it (the system) are compressed, so the air's internal energy and temperature increase. Work is being done on the system, so W is a negative quantity. The rapid squeezing of the balloon can be treated as an adiabatic process, so $Q = 0$ and, therefore, $\Delta U = -W$.

After the compression step, energy is transferred from the system as heat (Q). Some of the internal energy of the air inside the balloon is transferred to the air outside the balloon. During this step, the internal energy of the gas decreases, so ΔU has a negative value. Similarly, because energy is removed from the system, Q has a negative value. The change in internal energy for this step can be expressed as $-\Delta U = -Q$, or $\Delta U = Q$.

The signs for heat and work for a system are summarized in **Table 1.** To remember whether a system's internal energy increases or decreases, you may find it helpful to visualize the system as a circle. When work is done on the system or energy is transferred as heat into the system, an arrow points into the circle. This shows that internal energy increases. When work is done by the system or energy is transferred as heat out of the system, the arrow points out of the circle. This shows that internal energy decreases.

Did you know?

Not all ways of transferring energy can be classified simply by work or by heat. Other processes that can change the internal energy of a substance include changes in the chemical and magnetic properties of the substance.

Table 1 Signs of Q and W for a System

$Q > 0$	energy added to system as heat
$Q < 0$	energy removed from system as heat
$Q = 0$	no transfer of energy as heat
$W > 0$	work done by system (expansion of gas)
$W < 0$	work done on system (compression of gas)
$W = 0$	no work done

The first law of thermodynamics can be expressed mathematically

In all the thermodynamic processes described so far, energy has been conserved. To describe the overall change in the system's internal energy, one must account for the transfer of energy to or from the system as heat and work. The total change in the internal energy is the difference between the final internal energy value (U_f) and the initial internal energy value (U_i). That is, $\Delta U = U_f - U_i$. Energy conservation requires that the total change in internal energy from its initial to its final equilibrium conditions be equal to the net transfer of energy as both heat and work. This statement of total energy conservation, shown mathematically on the next page, is the first law of thermodynamics.