Second Law of Thermodynamics

The second law of thermodynamics is useful in examining the direction of energy transfer or conversion. The following two statements of the second law are by Rudolf Clausius and Lord Kelvin respectively.

No process is possible whose sole result is the removal of heat from a reservoir (system) at one temperature and the absorption of an equal quantity of heat by a reservoir at a higher temperature.

No process is possible whose sole result is the abstraction of heat from a single reservoir and the performance of an equivalent amount of work.

The second law of thermodynamics helps explain why heat always flows from a hot object to a cold object; why two gases placed in a chamber will mix throughout the chamber, but will not spontaneously separate once mixed

The second law of thermodynamics assigns both quantity and quality to energy. The importance of this law is evident in any process—the path of a process is always toward that of decreasing quality. For example, a hot bowl of soup left to itself on a table cools down. In this case, the quality of energy degrades. Energy of a higher quality (at a higher temperature) transfers from the soup to the surroundings and converts into less useful forms of energy.

ENERGY

Energy may be in different forms, such as potential, kinetic, chemical, magnetic, or electrical.

Potential energy of a system is by virtue of its location with respect to the gravitational field. If an object has a mass *m*, located at elevation *h*, and acceleration due to gravity is *g*, then the potential energy is

$E\mathrm{PE} = mgh$

Kinetic energy of an object is due to its velocity. If an object is moving with a velocity *u*, and it has mass *m*, then its kinetic energy is

$E\text{KE} = 1/2mu^2$

Both kinetic and potential energies are *macroscopic*; that is, they represent energy of a system due to its entire being. This is in contrast to internal energy, which is due to the *microscopic* nature of a system.

At the molecular scale, the atoms of a substance are continuously in motion. They move in random direction, collide with each other, vibrate, and rotate. Energies related to all these movements, including energy of attraction between the atoms, is combined into one lump sum and is called the internal energy.

Internal energy is an extensive property, and it is independent of the path of a process. Although we cannot measure an absolute value of internal energy, we can relate changes in internal energy to other properties such as temperature and pressure. In many engineering systems, one or two forms of energy may dominate whereas others can be neglected. For example, when a sugar beet is dropped from a conveyor into a bin, the potential and kinetic energy of the sugar beet changes, but other energy forms such as chemical, magnetic, and electrical do not change and may be neglected in the analysis. Similarly, when tomato juice is heated in a hot-break heater, the potential or kinetic energy of the juice does not change, but the internal energy will change as temperature increases.

If the magnitudes of all other energy forms are small in comparison with the kinetic, potential, and internal energies, then

$E\text{TOTAL} = E\text{KE} + E\text{PE} + E\text{i}$

ENERGY BALANCE

The first law of thermodynamics states that energy can be neither created nor destroyed. We may express this in the form of a word equation as

Total energy entering the system - Total energy leaving the system = Change in the total energy of the system

Therefore, when a system is undergoing any process, the energy entering the system minus that leaving the system must equal any change in the energy of the system, or

$E_{in} - E_{out} = \Delta E_{system}$