

Lecture 8 The First Law of Thermodynamics

(Ch. 3 First Law of Thermodynamics)

Principle of Conservation of Energy: The energy of all sorts (e.g., *KE*, *PE*, *work*, *heat*) can neither be created nor destroyed.

Note, however, **energy can be converted to different forms** by various means **and can be transferred among different systems and regions.**

When energy is added to (extracted from) a system, the final energy is equal to the original energy plus (minus) the energy added (extracted).

For a closed system (constant mass), the first law of thermodynamics can be expressed mathematically as:

$$\Delta Q = \Delta E + \Delta W \quad (3.14)$$

or

$$\Delta E = \Delta Q - \Delta W \quad (3.15)$$

where ΔE : total energy change,
 ΔQ : heat added to the system,
 ΔW : work done on the environment by the system.

Equation (3.14) states that for a closed system, the amount of heat added to the system can be used to increase the total energy of the system and/or to cause the system to do work.

In other words, for a closed system, the total energy change is the difference between the heat added to the system and the work done by the system.

The above statements are also called the **First Law of Thermodynamics** (Eq. (3.14) or (3.15)).

In thermodynamics, the total energy change of a system (ΔE) consists of three different types of energy:

$$\Delta E = \Delta KE + \Delta PE + \Delta U \quad (3.16)$$

where ΔKE : Change in macroscopic kinetic energy
 ΔPE : Change in macroscopic potential energy
 ΔU : Change in internal energy

The *internal energy* (U) is composed by:

- (1) *Microscopic kinetic energy* in forms of molecular random motions - manifested as increases in the temperature of the body,

$$KE = \frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$$

- (2) *Microscopic potential energy* in forms of intermolecular configuration.

If there is no change in macroscopic kinetic and potential energy (e.g. a stationary system), then (3.15) becomes

$$\Delta U = \Delta Q - \Delta W \quad (3.17)$$

or in differential form:

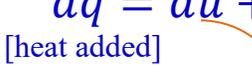
$$dU = dQ - dW \quad (3.18)$$

Dividing (3.18) by mass m leads to,

$$du = dq - dw, \quad (3.19)$$

or

$$dq = du + dw$$

[heat added]  [increase internal energy of the system]  [work done on the environment]

where du is the *change in specific internal energy*,
 $dq = dQ/m$ is the *change in specific heat*,
 $dw = dW/m$ is the *change in specific work*.

Either (3.17), (3.18), or (3.19) expresses the First Law of Thermodynamics. That is, the change of total internal energy of a closed system is equal to the heat transferred to the system minus the work done by the system on its environment.

Recall that

$$dw = p d\alpha. \quad (3.3)$$

Substituting (3.3) into (3.19) yields another form of the first law,

$$du = dq - p d\alpha.$$

or

$$dq = du + p d\alpha. \quad (3.20)$$