13

Concepts and Units of Energy

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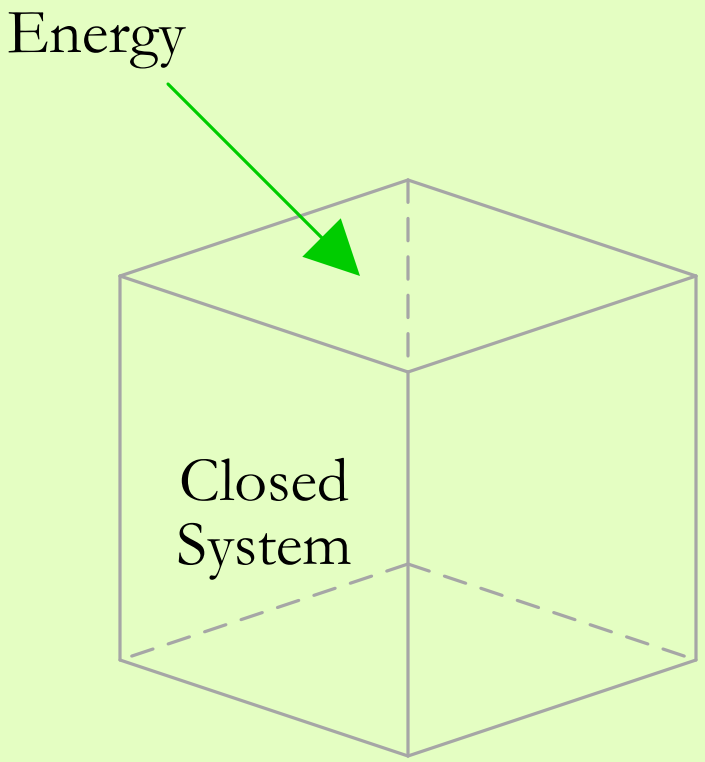
"Energy can neither be created nor destroyed"



$$\Delta E_{system} = E_{transferred}$$

The six important forms of energy are:

- Work (W)
- Heat (Q)

forms of energy that can be transferred

- Kinetic Energy (K)
- Potential Energy (P)
- Internal Energy (U)
- Enthalpy (H)

forms of energy that can be possessed by a system

Work (W)

Form of energy that is transferred due to a mechanical force. Work cannot be stored by the system. As a convention,

(+) : system ======> surroundings
(--) : surroundings ======> system

Mathematically,

$$W = \int F \cdot dx = \int P \cdot dV$$

where F, x = mechanical force and displacement
P, V = pressure and volume

Heat (Q)

Form of energy that is transferred due to a temperature difference. Heat cannot be stored by the system. As a convention,

(+) : surroundings ======> system
(--) : system ======> surroundings

Mathematically,

$$Q = UA\Delta T$$

where U = heat-transfer coefficient (empirical)
A = area for heat transfer
ΔT = temperature difference

Kinetic Energy (K)

Form of energy stored by the system as indicated by its velocity relative to the surroundings.

It may be calculated from the relation

$$K = \frac{1}{2} mv^2$$

where m = mass of the system
v = velocity of the system

Potential Energy (P)

Form of energy stored by the system because of its position in a potential field such as a gravitational field.

In a gravitation field, it may be calculated from the relation

$$P = mgh$$

where
- m = mass of the system
- g = acceleration due to gravity = 9.6 m/s^2 = 32.2 ft/s^2
- h = distance from a reference height

Internal Energy (U)

Internal energy is a macroscopic measure of the molecular, atomic, and subatomic energies. There is no direct way of measuring internal energy but It is known to depend on T and P.

$$U = f(T,V)$$

Taking the total derivative of U,

$$dU = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV$$

For all practical purposes, the second-term is small compared to the first term. Hence,

$$dU = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV \approx \left(\frac{\partial U}{\partial T}\right)_V dT$$

By definition, $(\partial U/\partial T)_V$ is the "heat capacity" at constant volume. Changes in internal energy (ΔU) can now be computed as

$$\Delta U = \int C_V dT$$

Enthalpy (H)

In energy balances, the terms (U + PV) appears very often, hence, it was defined accordingly and referred to as enthalpy.

$$H = U + PV = f(T,P)$$

Taking the total derivative of H,

$$dH = \left(\frac{\partial H}{\partial T}\right)_P dT + \left(\frac{\partial H}{\partial P}\right)_T dP$$

For all practical purposes, the second-term is small compared to the first term. Hence,

$$\mathrm{dH} = \left(\frac{\partial \mathrm{H}}{\partial \mathrm{T}}\right)_{\mathrm{P}} dT + \left(\frac{\partial \mathrm{H}}{\partial \mathrm{P}}\right)_{\mathrm{T}} dP \approx \left(\frac{\partial \mathrm{H}}{\partial \mathrm{T}}\right)_{\mathrm{P}} dT$$

By definition, $(\partial \mathrm{U}/\partial \mathrm{T})_{\mathrm{P}}$ is the "heat capacity" at constant pressure. Changes in enthalpy (ΔH) can now be computed as

$$\Delta \mathrm{H} = \int \mathrm{C_P} dT$$

Recall: The dimension of energy is

$$E = \frac{m \cdot L^2}{\theta^2}$$

The corresponding unit in SI is

$$E = \frac{kg \cdot m^2}{s^2} = N \cdot m = J$$

For the english system, the **british thermal unit** (Btu) is used. Sometimes, the thermochemical **calorie** (cal) is also used.