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Department of Medical Physics
The Second Stage
Thermodynamics and Heat
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Lecture .2

Energy (E) :

Is the work (w) performed or consumed by the material, the are two kind of energy (stored energy and transient or transmitted energy). stored energy have several forms : chemical, electrical, internal energy, mechanical (The potential and kinetic energy). While the transient energy, it is of two forms: heat and work

Internal energy

It is the sum of the energies possessed by all the particles involved in the formation of the system .These energies are:

1. transitional kinetic energy.
2. Rotational energy.
3. Vibrational kinetic energy
4. Potential energy
5. Nuclear and electronic energies

Kinds of Energy:

Energy have different kinds of energy and can turn any kind into other , the most important kinds of energy are:

1- Thermal energy

2- Atomic energy

3- Mechanical energy

4- Electric energy

5-Chemical Energy

6- Internal energy

7- Optical energy

8- Sound energy

The relationship between energy (E) and the mass (m) can be illustrated as follows:

$E=W$

$E= F \times d$

$E= (m \times a) \times d$

$E= m \times d \times (v / t)$

$E= m \times v \times (d / t)$

$E= m \times v \times v = m \times v^2$

That is, the energy is equal to the mass of the material in the speed of this material, that similarity to Einstein's equation in which he determined that the energy of the body which consists of light that named the photon (E) is equal to the mass of material in the square of its velocity, that equal to the speed of light **c**

$$E = m \times c^2$$

From the Mechanical side the energy is divided into two types:

1- Kinetics Energy (K. E) that depends on the mass of the body **m** and at velocity **v** and equal to:

$$K.E = 1/2\ m\ v^2$$

Example:

Calculate the movement of a body mass of 60 kg and its speed of 20 km / h?

Solution:

$K.E = 1/2\ m\ v^2$

$= 1/2 \times 60 \times [(20 \times 1000) / 60 \times 60]^2$

$= 925.925$ J

2- Potential Energy (P. E) that depends on the mass of body **m** and its acceleration **a** and the distance traveled **d** .

P. E = m x a x d

Example:

An object moving at an acceleration equal to (20 m / s^2) and a mass of 300 kg find the Potential energy if a distance of 1 m ?

Solution:

P . E = m x a x d

= 300 kg x 20 m / s^2 x1 m

= 6000 kg m^2 / s^2

= 6000 J = 6 kJ

All energy kinds have units of (mass x (length) ^{2} / (time) ^{2}) , therefore energy can be in the **Erg** unit, or **Joule** unit or **Calory**.

The energy unit in the system (**cgs**) is French origin and means (cm. Gram. Sec) is the **erg** . It is defined as the amount of work done when a force of one dyne travelling at a distance of one cm.

Dyne :Is a force that gives a wheel of 1cm / sec^2 to a body mass of one gram.

Relations between units

Calorie = 4.18 J.

Joule = 107 erg.

Heat Capacity

Known as the amount of thermal energy needed to raise the temperature of a particular body have mass (m) one degree Celsius. Heat Capacity Unit (J / C^o) .

Specific Heat

It is defined as the thermal capacity of each gram of material , that represented amount of thermal energy needed to raise the temperature one gram of material one degree Celsius. Specific heat unit (J / g Cº)

Molar Heat Capacity

Is the amount of energy needed to raise the temperature of one mole of the material one degree Celsius, and its unit (J / mole Cº) .

For water: Molar thermal capacity is the thermal capacity of 18 g of

Water is equal to 18 x 4.18 = 75.3 J / mole

Uses of heat capacity

Depending on the thermal capacity, we can be calculated the amount of heat (q) required to raise the temperature system that have fixed mass from initial temperature (T_1) to final temperature (T_2):

$$\mathbf{q = C\ (T_2 - T_1)}$$

$$\mathbf{q = C\ \Delta\ T}$$

Since the thermal capacity = mass x the specific heat

$$\mathbf{C = m \times \rho}$$

Where the material specific heat = ρ , mass of material = m

Therefore, the amount of heat lost or acquired is calculated from the relationship:

$$\mathbf{q = C\ \Delta\ T = \rho \times m \times \Delta\ T}$$

Thermal capacity at constant volume (Cv) and at constant pressure (Cp)

Cv Thermal Capacity :is heat obtained at a constant volume is used only to raise the kinetic energy of molecules, while the heat obtained at the constant pressure of Cp is used for a particular work due to the expansion and contraction of the gas, in addition to raise the kinetic energy of molecules.

Mathematically It can be expressed as follows:

$$Cv = dE / dT$$

$$Cp = dH / dT$$

For an ideal single-atomic gas, kinetic energy transitional is ((3/2) R T)

$$Cv = d (3/2\ RT) / dT$$

$$= 3/2\ R\ d\ T / d\ T$$

$$= 3/2\ R$$

$$Cv = 3/2\ R \text{ -------- } (1)$$

$$Cp = d\ H / d\ T$$

$$= d\ (E + PV) / d\ T$$

$$= d\ E / d\ T + d\ (PV) / dT$$

When the pressure is constant :

$$Cp = d\ E / d\ T + P\ d\ V / d\ T$$

For one mole of ideal gas where:

$$PV = RT$$

When the pressure is constant: $P\ d\ V = R\ dT$

$$Cp = d\ E / d\ T + R\ d\ T / d\ T$$

$$= Cv + R \text{ ---------- } (2)$$

$$Cp = Cv + R$$

Example:

Determine Cp, Cv for mono-atomic ideal gas?

Solution :

$Cv = dE / dT$

$Cv = d\ (3 / 2RT) / d\ T$

$= 3 / 2R = (3 / 2)\ x2 = 3\ Cal\ .mol^{-1}deg^{-1}$

$Cp = Cv + R$

$5 / 2R = 5\ Cal.mol^{-1}deg^{-1}$

- Since most materials expand when heated, Cp is regularly larger than Cv.

- For an ideal gas, Cp is greater than Cv by R.

Definition of some thermodynamic variables

Variable	**Name**	**Definition equation**	**International Unity and Symbol**
P	Pressure	P= Force/Area	Pascal (Pa) , N/m^2
V	Volume	Space in 3-dimention	m^3
T	Temperature	----------------	Kelvin (K)
N	The Mole	Weight/ Equivalent weight	Mole
W	Work	W=Force* distance W=Volume*Pressure	Joule (J)
Q	Thermal Heat	-----------------	Joule (J)