University of Mosul

College of Science

Department of Physics

Second Stage

Heat and Thermodynamic

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Lecture 8: The first law of thermodynamics

Preparation

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Chapter four

The first law of thermodynamics

The first law of thermodynamics is a special form of the law of energy conservation, which states (Energy is not perishable and not created, but can be transferred from one doubt to another). The first law of thermodynamics deals in particular with transient energy, that is, that travels across the boundaries of the system, such as heat and work. These two forms of energy exist only when entering or leaving an entity.

There are many experiments that led to the approval of this law, the most important of which is Gul's experiment, in which he emphasized the existence of a relationship between work and the amount of heat,

$W= JQ$……………..(1)

which is that the amount of work performed is equivalent to the amount of energy generated or vice versa Thus, it can be said that work and heat quantities are always equivalent and can be expressed in the same units, either calorie or joule **1Cal. =4.2 Joule** .

We can consider Equation No. 1 another mathematical formula for the first law of a closed system that passes through one or more revolutions In practice, if a certain amount of heat enters a system, the incoming heat is not completely transformed into work. Part of the heat that the system is equipped with is used to complete external work on the perimeter, and the remaining part is used to increase the internal energy of the system.

If we assume that the amount of heat prepared for the system during any process is Q and the external work performed is W, U_1 represents the internal energy of the system at the beginning of the process and U_2 represents its internal energy at the end of the process. The mathematical relationship between these quantities is

$$Q = W + (U_2 - U_1) \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

This equation represents the first law of thermodynamics, and all quantities are measured in units of energy (joules or calories). Equation 2 can be written in the differential formula, especially when the system absorbs a small amount of heat dQ and accomplishes a small amount of work dW

$$dQ = dW + dU \ldots\ldots\ldots\ldots\ldots..(3)$$

And Accordingly, the first law of thermodynamics states that (the difference between the amount of heat added to the system and the amount of work transferred from the system to the surrounding environment is equal to the amount of increase in the internal energy of the system). That is, the net energy passing between the system and its surroundings is equal to the amount of change in the internal energy of the system

Internal energy:

the internal energy depends on the state of the system only and not on the method of conducting the operation on the system to change its state. Therefore, if the system goes through a full cycle, it becomes painful after the end of the process to the same initial state, then the amount of change in the internal energy of the system is equal to zero. That is, in any complete periodic process the periodic integration of the internal energy is zero, i.e. that:

$$\oint dU = 0 \ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

If we complete equation 3 for a full turn it results

$$\oint dQ = \oint dW + \oint dU \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Substituting in equation 4 into equation 5, we find that

$$\oint dQ = \oint dW \ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

This equation represents Joule's law

Results of the first law in thermodynamics:

There are several important conclusions that can be drawn from applying this law to the various operations that take place under different circumstances. Below we will discuss some of these results

1. Inverse process : If we have a simple system, its state can be determined in terms of mass and pressure

Temperature and volume, if the system gives a small amount of heat of dQ, and through a quasi-static process, the amount of work W that the system performs on the surrounding due to its volume expansion is pdv. When applying the first law in such an inverse process, it results

$$dQ = dU + PdV$$

2. adiabatic processes: In this process, no heat enters or exits the system. $dQ = 0$. Therefore, the first law becomes as follows.

$$dW = - dU$$

In other words, the work performed by the system is equal to the amount of the decrease in its internal energy, meaning that the external work is at the expense of the internal energy of the system

3 . The internal energy (or temperature changes under a constant volume):

if the system is supplied with an amount of heat without changing the volume, then the work performed in this process is zero because the amount of change in volume is $dV = 0$, so the first law becomes $dQ = dU$, which means that The amount of heat entering or leaving the simple system under a fixed volume is equal to the amount of change in the internal energy

4. isothermal processes: In these processes the dT is zero, so the change in the internal energy will be zero, so dW = dQ. That is, the change in the amount of heat depends on the work performed by changing the volume.

Enthalpy -: temperature changes under constant pressure:

from the differential formula of the first law

$$\mathbf{dQ = dU + PdV \ldots\ldots\ldots\ldots (7)}$$

We notice that the amount of change in the amount of heat dQ is an incomplete differential, so if the system passes from the initial state A to the final state B, it produces

$$\oint_{A}^{B} dQ = \oint_{A}^{B} dU + \oint_{A}^{B} PdV \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The first and second terms of the right side of equation (8) cannot be integrated unless we know the differential of the path connecting the initial and final states, so if we assume that the simple system absorbed heat under constant pressure, then the path is known (i.e., the path is determined by changing the size of the system with constant pressure Therefore, equation (8) will be in the following form

$$\oint_{A}^{B} dQ = \oint_{A}^{B} dU + P\oint_{A}^{B} dV \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

After integrating this equation it results $Q = U_2 - U_1 + P(V_B - V_A)$……………….(10)

Where Q represents the amount of heat absorbed or emitted by the system under constant pressure, we arrange Equation No. (10), resulting in

$Q = (U_2 + PVB) - (U_1 + PVA)$ ……………… (11)

The magnitude U + PV is a new function called enthalpy and is denoted by the symbol H,

$H = U + PV$………………….(12)

and therefore equation No. 11 will be

$Q = H_2 - H_1$………………….(13)

OR $Q = \Delta H$

Accordingly, for any reverse process under constant pressure, the amount of heat transferred is equal to the change in enthalpy (That is, the amount of heat that is absorbed or emitted by the system during an inverse process under constant pressure equals the change in the enthalpy from the initial state to the final state)

The meaning of enthalpy: It is defined as the sum of the internal energy U and the product of pressure multiplied by the volume PV. This definition is not a specific physical concept, but has acquired its own meaning for purely mathematical reasons. The expression U + PV appears in many of the equations used in thermodynamics, so it is preferable to use the symbol H instead of U + PV.

The physical meaning of enthalpy is given through the following examples:

a. If we have a pure system of mass m, then if the system transforms from a solid state to a liquid state or from a liquid state to a vapor state, it absorbs a quantity of heat called the transfer heat and denoted by the letter L, which is defined as the ratio between the amount of heat required Q to convert the system state from one state to another to another The mass of the entity m.

$$\mathbf{L = \frac{Q}{m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)}$$

That is, the process of changing the state of the entity from one state to another takes place under a constant temperature (isothermal process) and is always accompanied by the crossing of heat and work.

The change of the state of the entity is accompanied by a change in the volume, and accordingly, there is work performed by the entity or on the entity (except for the critical point at which the volume of liquid or vapor is the same).

If the change in volume takes place without change in temperature and under constant pressure, then the work performed by the entity is W, i.e.

$W = P (V_2-V_1)$ ………… .. (15)

Where V_1 and V_2 are the initial and final volumes. By applying the first law, we get

$Q = mL = U_2-U_1 + P (V_2-V_1)$ …………… (16)

Sort this equation

$mL = (U_2 + PV_2) - (U_1 + PV_1)$ ………………. (17)

$mL = H_2- H_1$ ………………………………. (18)

$L = h_2-h_1$ ………………………………… ... (19)

Where h_1 and h_2 represent the primary and final enthalpies respectively. That is, the transfer temperature L is equal to the difference between the specific enthalpy of the entity before and after the conversion.

Example: If the amount of heat entering a certain entity in a process was 600 calories, and the work performed on this entity at the same time was 16 joules, what is the amount of increase in its internal energy?

1cal= 4.2 Joul

dQ=dW+dU , 600*4.2 – 16 = dU , dU = 2504 Joul = 596.2Cal.