

Internal Energy:

Internal ~~energies~~ energy is the sum of molecular kinetic and potential energies in the frame of reference relative to which the centre of mass of the system is at rest.

Internal energy is generally defined as 'U'.

*. Although we have invoked the molecular picture to understand internal energy (U) but as far as thermodynamics is concerned, internal energy (U) is a macroscopic variable of the system.

*. Internal energy depends only on the state of the system not on how that state is achieved. Internal energy (U) is a thermodynamic state variable.

~~*. In experience~~

~~*. Experience shows, internal energy of a system can be~~

*. Experience shows, there are two ways to change the state of a system (and hence its internal energy).

one way is ~~to~~ by supplying heat to the system or taking heat out of the system.

The other way is by doing work on the system or doing

work by the system.

*. Thus, heat and work in thermodynamics are not state variables. They are modes of energy transfer to a system resulting in change in its internal energy.

*. Hence, 'Internal' energy' is a state variable and 'Heat' & 'work' are path variables.

~~Part~~

First Law of Thermodynamics:-

According to 1st law of thermodynamics, the energy (ΔQ) supplied to the system goes in partly to increase the internal energy (ΔU) and the rest in work done by the system on the environment (ΔW).

i.e.

$$\Delta Q = \Delta U + \Delta W \quad \rightarrow \textcircled{1}$$

Equation $\textcircled{1}$ is the mathematical form of 1st law of thermodynamics.

Note: First law of thermodynamics is simply the general law of conservation of energy applied to any system in which the energy transfer from or to the surroundings

is taken into account.

*. Since U is a state variable, ΔU depends only on the initial and final states and not on the path taken by the gas to go from one to the other.

ΔQ and ΔW are however are path functions as they are dependent on the path taken.

It is clear that the combination $(\Delta Q - \Delta W) = \Delta U$, is path independent.

Question: Prove that for an isothermal expansion of an ideal gas, $\Delta Q = \Delta W$ (i.e. heat supplied to the system is used up entirely by the system in doing work on the environment.)

Proof:-

For an ideal gas, internal energy is a function of temp only. i.e. $U = U(T) \rightarrow \text{①}$

In an isothermal process, the temp of a system will remain constant when a system is taken from its initial to final state. Hence, change in internal energy of the system of a system of ideal gases when taken from initial to final state is zero. i.e.

$$\Delta U = 0 \rightarrow \text{②}$$

From the 1st law of thermodynamics,

$$\Delta U = \Delta Q - \Delta W \rightarrow (3)$$

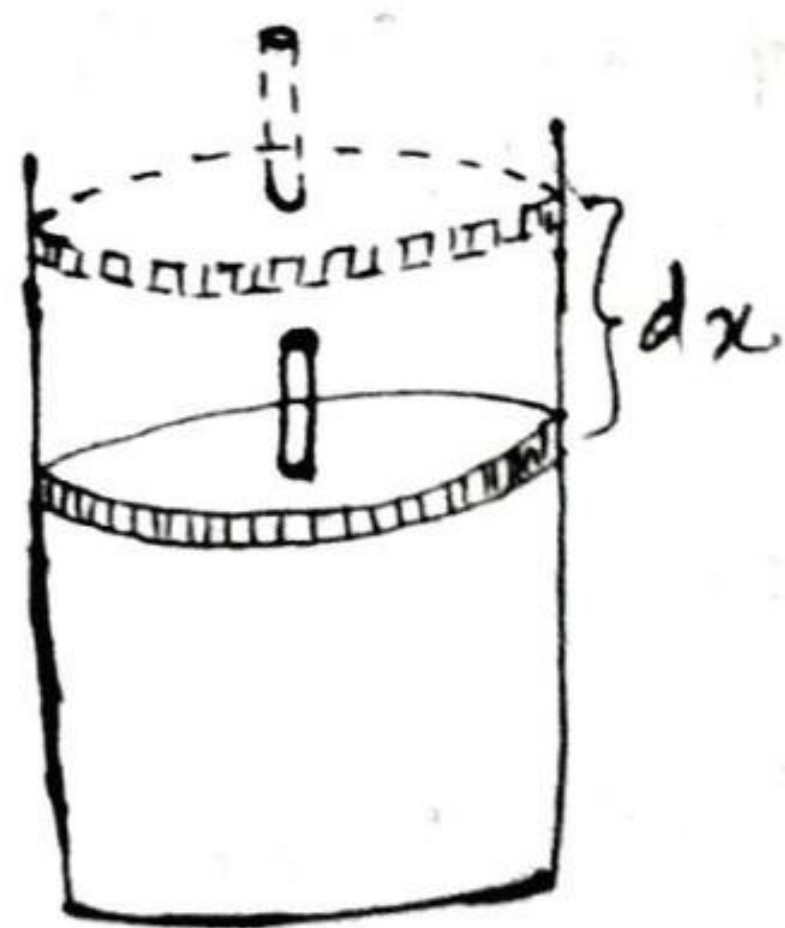
Using equaⁿ (2) \Rightarrow

$$\Delta Q - \Delta W = 0$$

$$\Rightarrow \Delta Q = \Delta W \rightarrow (4)$$

Thus, for isothermal ~~exp~~ expansion of an ideal gas, heat supplied to the system is used up entirely by the system in doing work on the environment.

work done in a gas cylinder with movable piston:



If the system is a gas in a cylinder with a movable piston, ~~the work~~ the gas in moving the piston does work. ~~same~~

Let F be the force acting on the piston having area A to make a displacement of ' dx '.

work done by the system is against a constant pressure,

~~is~~

P is,

$$\Delta W = F \cdot dx$$

$$= P \cdot A \cdot dx \quad (\text{since } P = F/A)$$

$$= P \cdot (A \cdot dx)$$

$$\Rightarrow \Delta W = P \Delta V$$

$$\boxed{\Rightarrow \Delta W = P \Delta V} \rightarrow \textcircled{1}$$

using equanⁿ $\textcircled{1}$, the 1st law of thermodynamics can be modified as:

$$\Delta Q = \Delta U + \Delta W$$

$$\boxed{\Rightarrow \Delta Q = \Delta U + P \Delta V} \rightarrow \textcircled{2}$$

Question: calculate the increase in the internal energy of 1 gm of water in transition from the liquid to the vapour phase.

Solⁿ: The measured latent heat of water is, 2256 J/gm.

i.e. 1 gm of water has latent heat of 2256 J.

$$\therefore \Delta Q = 2256 \text{ J.}$$

At atmospheric pressure,

1 gm of water has a volume of 1 cm^3 in liquid phase.

1 gm of water has a volume of 1671 cm^3 in vapour phase.

$$\text{i.e. } V_i = 1 \text{ cm}^3$$

$$V_f = 1671 \text{ cm}^3$$

Therefore, work done (ΔW) = $P \Delta V$

$$= P \times (V_f - V_i)$$

$$= ~~1.013 \times (1671 - 1) \times 10^{-6}~~$$

$$= 1.013 \times 10^5 \times (1671 - 1) \times 10^{-6} \text{ J}$$

$$= 169.2 \text{ J}$$

Hence,

$$\Delta U = \Delta Q - \Delta W$$

$$= (2256 - 169.2) \text{ J}$$

$$= 2086.8 \text{ J}$$

Therefore, internal energy of water increases in transition from the liquid to the vapour state.