# First law of thermodynamics and it's applications.

First law of thermodynamics is infact a particular form of general law of conservation of energy applied to a thermodynamic system.

According to this law, if $dQ$ be the amount of heat supplied to a system, such that it's internal energy is increased by an amount $dU$ and work done by the system on it's surrounding is $dW$, then

$$\boxed{dQ = dU + dW} \quad \text{—(i)}$$

If the volume of the system does not change ($dV=0$) then the work done $dW = 0$. Hence from eqn (i) we get

$$dQ = dU + 0$$

$$\boxed{dQ = dU}$$

Thus, the Total heat supplied is used to increase the internal energy of the system. This thermodynamic process is called Isochoric process.

If even supplying the heat to system temp of the system remains constant, i.e the process is isothermal, then the increase in internal energy ($dU$) of the system is zero. Hence from eqn (i) we get

$$dQ = 0 + dW$$

$$\boxed{dQ = dW}$$

Thus in Isothermal process, total

heat supplied is used in work done by the system.

If heat does not supplied to system i.e

$dQ = 0$, then from eqn (1) we get

$$0 = dU + dW$$

$$\boxed{dW = -dU}$$

Thus, the work done by the system is at the cost of decrese of its internal energy. This is the adiabatic process.

Since, in cyclic process, the system returns to its initial state at the end of the cycle, thus the change in internal energy of the system $(dU)$ in cyclic process is zero. Thus again from equation (1) we get

$$dQ = 0 + dW$$

$$\boxed{dQ = dW}$$

Hence, in cyclic proess the total heat supplied is used or converted into work.

## Relation between $C_p$ & $C_v$ :-

Let $dQ$ be the amount of heat supplied to one mole of an ideal gas at const volume, such that its temp increased by $dT$, then

$$dQ = 1 \times C_v \times dT$$ ($C_v$ = molar specific heat of the gas at const volume)

or $$dQ = C_v dT \quad \text{--- (i)}$$

Here heat supplied is at const volume thus the change in its volume $dv = 0$, hence the work done is zero.

$\therefore$ $$dW = p\,dv$$

or $$dW = p \times 0$$

or $$dW = 0$$

$\therefore$ From 1st law of thermodynamics, we get

$$dQ = dU + dW$$

or $$C_v dT = dU + 0$$

or $$dU = C_v dT \quad \text{--- (ii)}$$

Now let heat $dQ'$ is given to the gas at constant pressure, so that its temp again increased by the same amount $dT$ & volume increased by $dV$, then we may write

$$dQ' = 1 \times C_p \times dT$$

or $$dQ' = C_p dT \quad \text{--- (iii)}$$ $C_p$ = Molar specific heat of the gas at const pressure

& work done

$$dW = p\,dV \quad \text{--- (iv)}$$

Now according to 1st Law of thermodynamics we may write

$$dq' = du + dw$$

or $C_p dT = C_v dT + p dv$ (By using eqn (ii), (iii), (iv))

or $C_p dT - C_v dT = p dv$

or $(C_p - C_v) dT = p dv$ — (v)

Since for one mole of an ideal gas we have

$$pV = RT$$

on differentiating both sides we get

$p dv = R dT$ — (vi) ($p$ = const, $R$ = const)

putting the value of eqn (vi) in (v) we get

or $(C_p - C_v) dT = R dT$

or $\boxed{(C_p - C_v) = R}$ — (vii)

This eqn (vii) is also known as Mayer's relation.

Note: Here $C_p$, $C_v$ & $R$ all are expressed in the same unit.