

## THERMODYNAMICS

Internal energy depends only on temperature and is independent of pressure and volume.

Internal energy = P.E + K.E, where potential energy is due to molecular configuration and K.E is due to molecular motion.

Internal energy of an ideal gas consists of only the K.E of molecules (P.E is absent because there are no intermolecular forces among the molecules in an ideal or perfect gas).

Internal energy of a real gas consists of P.E and K.E.

The amount of work performed is directly proportional to the amount of heat produced ( $W \propto H$ ).

$W = JH$ , where J is known as mechanical equivalent of heat or **Joule's constant**. J is equal to the amount of work required to produce one calorie of heat. Its value is equal to 4.186 joule/calorie. SI unit is J/kcal. The statement  $W = JH$  is also called the non-differential form of the first law of thermodynamics.

$$J = 4.186 \text{ J/cal} = 4.186 \times 10^7 \text{ erg/cal} = 4186 \text{ J/Kcal}$$

When heat and work are in Joule then  $J = 1$ .

The height from which ice is to be dropped to melt it completely is

$$h = \frac{JL}{g} \text{ where } L = \text{latent heat of ice.}$$

The rise in temperature of water when it falls from a height h to the ground is

$$\Delta\theta = \frac{gh}{Js} \text{ where 's' is specific heat of water.}$$

When a body of mass m moving with a velocity v is stopped and all of its energy is retained by it,

$$\text{then the increase in temperature is } \Delta\theta = \frac{v^2}{2Js}$$

When a block of ice of mass M is dragged with constant velocity on a rough horizontal surface of coefficient of friction  $\mu$ , through a distance d, then the mass of ice melted is

$$m = \frac{\mu Mgd}{JL} \text{ where } m = \text{mass of ice melted.}$$

When a block of mass m is dragged on a rough horizontal surface of coefficient of friction  $\mu$ , then the

$$\text{rise in temperature of block is } \Delta\theta = \frac{\mu gd}{Js}$$

If a bullet just melts when stopped by an obstacle and if all the heat produced is absorbed by the bullet then

$$ms\Delta\theta + mL = \frac{1}{2} \frac{mv^2}{J}$$

where L = latent heat of the material of the bullet  
s = specific heat

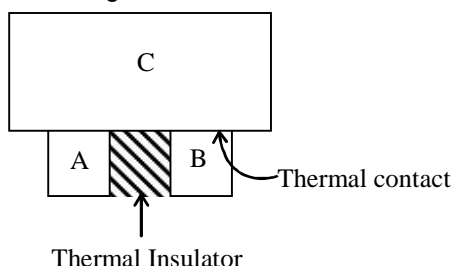
A metal ball falls from a height ' $h_1$ ', and bounces to height ' $h_2$ '. The rise in temperature of the ball is

$$\Delta\theta = \frac{g(h_1 - h_2)}{Js}$$

Joule's law or Mayer's hypothesis : It states that there is no change in internal energy during the free expansion of gas.

## ZEROETH LAW OF THERMODYNAMICS

According to it if two systems A and B are, separately in thermal equilibrium with a third system C, then the systems A and B when brought into thermal contact will also be in thermal equilibrium.



This law indicates that for systems in thermal equilibrium there must exist a common property which remains the same. This property is the "temperature". Thus Zeroth law, defines temperature.

For two bodies or systems in contact, heat flows from higher temperature to lower temperature. Temperature gives a measure of the hotness or coldness of a body

## FIRST LAW OF THERMODYNAMICS

This law is based on law of conservation of energy.

. If  $\delta Q$  = Heat supplied to a thermodynamical system

$\delta W$  = Work done by thermodynamical system

$dU$  = Change in internal energy

Then if there is no energy loss, the first law of thermodynamics gives.

$$\delta Q = \delta W + dU$$

Note :

(i)  $\delta Q$ ,  $\delta W$  and  $dU$  must be in the same units.

(ii) **Sign conventions**

Heat supplied to the system = (+)ve

Heat rejected to the system = (-)ve

Work done by the system = (+)ve

Work done on the system = (-)ve

If temperature increases  $dU$  = (+)ve

If temperature decreases  $dU = (-)ve$

Heat is the energy which is transferred between a system and its environment because of the temperature difference between them. It is given by,

$$\delta Q = nC_dT$$

where C is molar specific heat

Work is defined as the energy that is transferred from one body to the other owing to the force that acts between them.

It is given by,

$$\delta W = PdV$$

## **SPECIFIC HEAT OF GASES**

A gas will have two specific heats.

- a) specific heat at constant volume ( $C_V$ )
- b) specific heat at constant pressure ( $C_P$ )

Specific heat depends only on the nature of material and temperature.

Water has largest specific heat among solids and liquids.

Among solids, liquids and gases specific heat is maximum for hydrogen.

Specific heat slightly increases with increase of temperature.

In liquids specific heat is minimum for mercury.

The value of specific heat may lie between 0 and  $\infty$ .

In isothermal process, the value of specific heat is  $\infty$  but in adiabatic process its value is zero.

Specific heat of water is maximum at 15°C and minimum at 37°C.

Specific heat of all substances is zero at 0 K.

Substances with highest specific heat are bad conductors of heat and with low specific heat are good thermal and electrical conductors.

The substance with large specific heat warms up slowly and cools down slowly

$C_P$  is greater than  $C_V$  and  $\frac{C_P}{C_V} = \gamma$

$C_P - C_V = R$  (for 1 mole of gas) where R is universal gas constant

$R = 8.3 \text{ J/mol-K}$

$C_P - C_V = r$  (for 1 g of gas)

where r is specific gas constant.

$$C_P - C_V = R/J \text{ (in heat units)}$$

**$C_V$ ,  $C_P$  and values of different gases :**

S.No.	Nature of gas	$C_P$	$C_V$	$\gamma = C_P/C_V$
1.	Monoatomic	$\frac{5}{2} R$	$\frac{3}{2} R$	$\frac{5}{3} = 1.67$
2.	Diatomic	$\frac{7}{2} R$	$\frac{5}{2} R$	$\frac{7}{5} = 1.4$
3.	Tri (or) Polyatomic	$4R$	$3R$	$\frac{4}{3} = 1.33$

$\gamma$  value is always greater than one. It depends upon the atomicity of a gas. It decreases with increase in atomicity.  $C_P = \gamma \frac{R}{\gamma - 1}$  and  $C_V = \frac{R}{\gamma - 1}$

$\gamma$  of mixture of gases : When  $n_1$  moles of a gas with specific heat at constant volume  $C_{V_1}$  is mixed with  $n_2$  moles of another gas of specific heat at constant volume  $C_{V_2}$  then

$$(C_V)_{\text{mixture}} = \frac{n_1 C_{V_1} + n_2 C_{V_2}}{n_1 + n_2} \quad (C_P)_{\text{mixture}} = (C_V)_{\text{mixture}} + R$$

$$\gamma_{\text{mixture}} = \frac{C_{P(\text{mixture})}}{C_{V(\text{mixture})}} \quad ; \quad \frac{n_1 + n_2}{\gamma_{\text{mix}} - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

Fraction of heat absorbed that is converted into internal energy is  $\frac{dU}{dQ} = \frac{C_V}{C_P} = \frac{1}{\gamma}$

Fraction of heat absorbed that is converted into workdone =  $\frac{dW}{dQ} = \frac{R}{C_P} = 1 - \frac{1}{\gamma}$