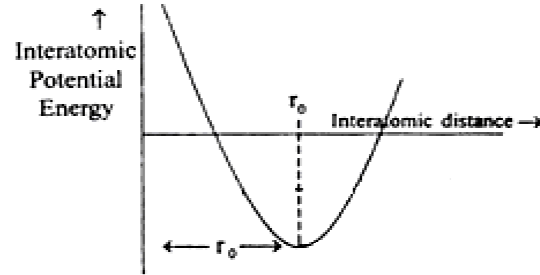
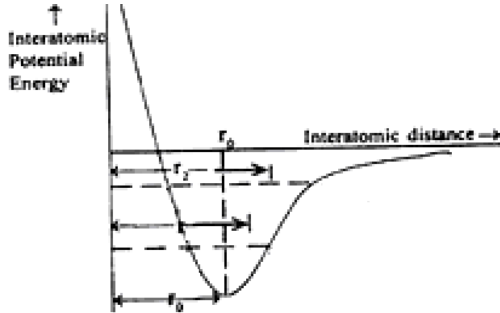


## EXPANSION OF SOLIDS

1. Lattice vibrations are purely harmonic and then PE curve is a symmetric parabola indicating no thermal expansion the average inter-atomic distance remains same
2. If the lattice vibrations are an-harmonic, PE curve is not a symmetric parabola indicating the thermal expansion. The average inter-atomic distance increases with increase of temperature.



3. Coefficient of linear expansion ( $\alpha$ ) : The ratio of increase in length per one degree rise in temperature to its original length is called coefficient of linear expansion.  $\alpha = \frac{l_2 - l_1}{l_1(t_2 - t_1)}$

Unit of  $\alpha$  :  $^{\circ}\text{C}^{-1}$  or  $\text{K}^{-1}$

4. Coefficient of area or superficial expansion ( $\beta$ ) : The increase in area per unit area per one degree rise in temperature is called coefficient of areal expansion.  $\beta = \frac{a_2 - a_1}{a_1(t_2 - t_1)}$

Unit of  $\beta$  :  $^{\circ}\text{C}^{-1}$  or  $\text{K}^{-1}$

5. The coefficient of volume or cubical expansion ( $\gamma$ ) is the increase in volume per unit volume per degree rise in temperature.  $\gamma = \frac{V_2 - V_1}{V_1(t_2 - t_1)}$

Unit of  $\gamma$  :  $^{\circ}\text{C}^{-1}$  or  $\text{K}^{-1}$

6. If  $\alpha_x, \alpha_y$  and  $\alpha_z$  denotes coefficient of linear expansions along X, Y, Z directions respectively,

$$\text{then } \alpha_{avg} = \frac{\alpha_x + \alpha_y + \alpha_z}{3} \Rightarrow \gamma = \alpha_x + \alpha_y + \alpha_z$$

7.  $\alpha : \beta : \gamma = 1 : 2 : 3$  or  $\gamma = 3\alpha$ ;  $\beta = 2\alpha$ ;

$$\gamma = \alpha + \beta.$$

8. The numerical value of coefficient of linear expansion of a solid depends on the nature of the material and the scale of temperature used.
9. The numerical value of coefficient of linear expansion of a solid is independent of physical dimensions of the body and also on the unit of length chosen.
10. The numerical value of  $\alpha$  or  $\beta$  or  $\gamma$  in the units of per  $^{\circ}\text{C}$  is 9/5 times its numerical value in the units of per  $^{\circ}\text{F}$ .

$$\alpha \text{ per } ^\circ\text{F} = \frac{5}{9} \alpha \text{ per } ^\circ\text{C}.$$

$$\alpha \text{ per } ^\circ\text{R} = \frac{5}{4} \alpha \text{ per } ^\circ\text{C}.$$

$$\alpha \text{ per K} = \alpha \text{ in } ^\circ\text{C}$$

11. The density of solid decreases with increase of temperature.  $d_t = \frac{d_o}{1 + \gamma t}$  Where  $d_o$  is density at  $0^\circ\text{C}$ .

12. If two rods of different materials have the same difference between their lengths at all temperatures, then  $\alpha_1 L_1 = \alpha_2 L_2$

$$\text{If the constant difference in their lengths is } x, \text{ then } L_1 = \left( \frac{\alpha_2}{\alpha_1 \sim \alpha_2} \right) x \quad \text{and } L_2 = \left( \frac{\alpha_1}{\alpha_1 \sim \alpha_2} \right) x$$

13. Pendulum clocks lose or gain time as the length increases or decreases respectively.

$$\text{The fractional change} = \frac{\Delta T}{T} = \frac{\alpha \Delta t}{2}.$$

$$\text{The loss or gain per day} = \frac{\alpha \Delta t}{2} \times 86400 \text{ seconds.}$$

14. If a metal rod is prevented from expansion on heating, stress will be developed, which is known as thermal stress.

$$\text{Thermal stress developed in the rod, } \frac{F}{A} = Y \alpha \Delta t$$

Thermal stress is independent of length of the rod.

15. As temperature increases, moment of inertia of a body increases. The Fractional change in moment of inertia is  $\frac{\Delta I}{I} = 2 \alpha t$

16. When the scale & body both are expanding  $l_{\text{correct}} = l_{\text{scale}} [1 \pm (\alpha_{\text{body}} - \alpha_{\text{scale}}) t]$

17. A metal scale is calibrated at a particular temperature does not give the correct measurement at any other temperature.

a) When scale expands correction to be made  $\Delta l = L \alpha \Delta t$ , correct reading  $= L + \Delta l$

b) When scale contracts correction to be made  $\Delta l = L \alpha \Delta t$ , correct reading  $= L - \Delta l$ .

$L =$  measured value.

$$L_{\text{measured}} = L_{\text{true}} [1 - \alpha(\Delta t)]$$

18. For a mercury barometer  $H_{\text{correct}} = H_{\text{scale}} [1 - (\gamma_{Hg} - \alpha_{\text{scale}}) t]$

### 19. Applications of expansions of solids:

a. A cavity of a solid object expands on heating just like a solid object of the same volume.

b. If a thin rod and a thick rod of same length and material are heated to same rise in temperature, both expand equally.

- c. If a thin rod and a thick rod of same length and material are heated by equal quantities of heat, thin rod expands more than thick rod.
- d. A metal plate contains two holes at a certain distance apart from each other. If the plate is heated, the distance between the centers of the holes increases.
- e. Platinum is used to seal inside glass because both have nearly equal coefficients of linear expansion.
- f. Iron or steel is used for reinforcement in concrete because both have nearly equal coefficients of expansion.
- g. Pyrex glass has low  $\alpha$ . Hence combustion tubes and test tubes for hating purpose are made out of it.
- h. Invar steel (steel + nickel) has very low  $\alpha$ . So it is used in making pendulum clocks, balancing wheels and measuring tapes. (Composition of invar steel is 64% steel and 36% nickel).
- i. Thick glass tumbler cracks when hot liquid is poured into it because of unequal expansion.
- j. Hot chimney cracks when a drop of water falls on it because of unequal contraction.
- k. A brass disc snugly fits in a hole in a steel plate. To loosen the disc from the hole, the system should be cooled.
- l. To remove a tight metal cap of a glass bottle, it should be warmed.
- m. While laying railway tracks, small gaps are left between adjacent rails to allow for free expansion without affecting the track during summer. Gap to be left  $(\Delta l) = \alpha l \Delta t = \text{expansion of each rail}$ .
- n. Concrete roads are laid in sections and expansion channels are provided between them.
- o. Thermostat is a device which maintains a steady temperature.
- p. Thermostats are used in refrigerators, automatic irons and incubators.
- q. Thermostat is a bimetallic strip made of iron and brass. The principle involved are different materials will have different coefficients of linear expansion.

$$= Y \Delta \alpha \Delta t = 2 \times 10^{11} \times 11 \times 10^{-6} \times 100 = 2.2 \times 10^8 \text{ N/m}^2$$