MSE-S304

Phase Transformation in Metals

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Kinetics of Homogeneous Nucleation

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⊙ Kinetics of Homogeneous Nucleation

- Homogeneous Nucleation → when probability of Nucleation at all points in the untransformed parent phase is equal.
- Let us Consider,
  ΔG_v is negative,
  σ is isotropic
  Embryos of the second phase are spherical.
- A critical embryo of radius r^* becomes stable nucleus of the precipitating phase with addition of one more atom to it.
- $\Delta G' = V \Delta G_v + A \sigma$

  $\Delta G' = \frac{4}{3}\pi r^3 \Delta G_v + 4\pi r^2 \sigma$ (for spherical embryo)

$$\left(\frac{\partial \Delta G'}{\partial r}\right)_{r=r^*} = 0$$

$$\Rightarrow 0 = \frac{4}{3}\pi \cdot 3r^2 \Delta G_v + 4\pi \cdot 2r\sigma$$

$$\Rightarrow 0 = 4\pi r^2 \Delta G_v + 8\pi r \sigma$$

$$\Rightarrow \boxed{r^* = -2\sigma / \Delta G_v}$$

For feasible transformation, ΔG_v is negative and hence r^* has a finite positive value.

Kinetics of Homogeneous Nucleation

⊙ Gibbs energy of formation of a critical embryo (ΔG^*)

- $\Delta G' = \frac{4}{3}\pi r^3 \Delta G_V + 4\pi r^2 \sigma$
- substitute r^* in place of r in above equation for getting the expression of ΔG^* :
- $\Delta G^* = \frac{4}{3}\pi (r^*)^3 \Delta G_V + 4\pi (r^*)^2 \sigma$
- $\Delta G^* = \frac{16\pi}{3} \cdot \frac{(\sigma)^3}{(\Delta G_V)^2}$

Kinetics of Homogeneous Nucleation

✓ Derive Per unit time relationship

Q:- Establish a relation b/w Gibbs energy of formation of a critical embryo & Vol.^{m} of critical embryo (Homogeneous nucleation)

Sol:- $\Delta G' = \frac{4}{3}\pi r^3 \Delta G_v + 4\pi r^2 \sigma \Rightarrow \partial \Delta G'/\partial r = 0 \Rightarrow 0 = \frac{4}{3}\pi \times 3r^2 \Delta G_v + 4\pi \times 2r\sigma$

$\Rightarrow r^* = -\frac{2\sigma}{\Delta G_v}$ & $\Delta G^* = \frac{16\pi}{3}\frac{\sigma^3}{(\Delta G_v)^2}$ & $V^* = \frac{4}{3}\pi (r^*)^3$

$\Rightarrow V^* = -\frac{32\pi}{3} \times \frac{\sigma^3}{(\Delta G_v)^2}$

$\therefore \boxed{\Delta G^* = -\frac{\Delta G_v V^*}{2}}$ Proved //

Kinetics of Homogeneous Nucleation

- Steady state concentration of critical embryos per unit volume of parent phase —

$$N_r^* = N_V \exp\left(-\frac{\Delta G^*}{kT}\right)$$

N_r^* → number of critical embryos per unit volume in the parent phase.

N_V → number of atoms per unit volume in the parent phase.