Tutorial problems and questions

1. The incoherent planar boundary that separates a precipitate and matrix thickens as

   (a) $\sqrt{Dt}$

   (b) $\sqrt{\frac{D}{t}}$

   (b) Dt

   (c) $\frac{D}{t}$

Answer

(a) $\sqrt{Dt}$

The growth is parabloic.

2. With increasing undercooling, the growth velocity of a precipitate-matrix interface

   (a) increases and hence peaks at highest undercooling
   (b) decreases and hence peaks at lowest undercooling
   (c) increases and then decreases and hence peaks at intermediate undercooling
   (d) decreases and then increases and hence peaks at both highest and lowest udercoolings

Answer

(c) increases and then decreases and hence peaks at intermediate undercooling.

See Fig. 24

3. The growth rate of an incoherent, planar precipitate-matrix interface is proportional to

   (a) ΔX_0

   (b) $(\Delta X_0)^2$

   (c) $\frac{1}{\Delta X_0}$

   (d) $\frac{1}{(\Delta X_0)^2}$

Answer

(a) ΔX_0

See. Eq. 57.

4. In general,

   (a) the mobilities of coherent and incoherent boundaries are the same
   (b) the mobility of coherent boundary is lower than that of incoherent boundary
   (c) the mobility of incoherent boundary is lower than that of coherent boundary

Answer

(b) the mobility of coherent boundary is lower than that of incoherent boundary

5. Derive Eq. 56from Eq. 55 by integration, and Eq. 57 from Eq. 56 by differentiation.

Answer

Consider Eq. 55

$$v = \frac{dx}{dt} = \frac{(\Delta X_0)}{(X_e^\beta - X_e^\alpha)} \sqrt{D} \frac{1}{2t^{\frac{1}{2}}}. \quad (66)$$

$$2x dx = \frac{D(\Delta X_0)^2}{(X_e^\beta - X_e^\alpha)^2} dt. \quad (67)$$

$$x^2 = \frac{D(\Delta X_0)^2}{(X_e^\beta - X_e^\alpha)^2} t. \quad (68)$$

$$x = \frac{(\Delta X_0)}{(X_e^\beta - X_e^\alpha)} \sqrt{Dt}. \quad (69)$$

This is Eq. 56. To obtain Eq. 57, let us start with the above equation and differentiate it with respect to time:

$$x = \frac{(\Delta X_0)}{(X_e^\beta - X_e^\alpha)} \sqrt{D} t^{\frac{1}{2}}. \quad (70)$$

$$v = \frac{dx}{dt} = \frac{(\Delta X_0)}{(X_e^\beta - X_e^\alpha)} \sqrt{D} \frac{1}{2t^{\frac{1}{2}}}. \quad (71)$$

Thus, we obtain the Eq. 57:

$$v = \frac{\Delta X_0}{2(X_e^\beta - X_e^\alpha)} \left(\sqrt{\frac{D}{t}} \right). \quad (72)$$

6. Consider the phase diagram shown in Fig. 29. Let T1, T2 and T3 be 1000, 650 and 600 K, respectively. Consider two pieces of an alloy of composition 0.25; let one be cooled from T1 to T2 and kept at T2 for about 2 minutes while the other is cooled from T1 to T3 and kept at T3 for about 2 minutes. Assuming incoherent and planar boundary between β nuclei and supersaturated α phase, calculate the increase in length of the precipitates in these two cases. The relevant diffusivity data is as follows: $D_0 = 1.2 \times 10^{-2} m^2/sec$ and Q = 150 kJ/mol.

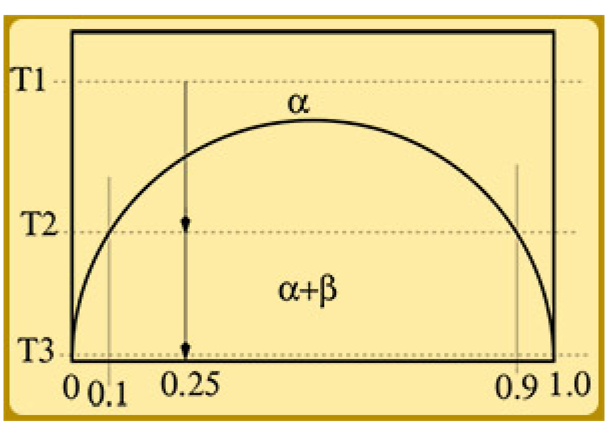

Figure 29: Schematic phase diagram to show the heat treatment. The overall alloy composition is 0.25. In one case, the alloy is cooled from T1 to T2 and is kept at T2 for 5 hours. In the other, the alloy is cooled from T1 to T2 and is kept at T3 for 5 hours.

Answer

We know that the increase in length is given by

$$x = \frac{(\Delta X_0)}{(X_e^\beta - X_e^\alpha)}\sqrt{Dt}. \quad (73)$$

Here, $\sqrt{Dt}$ is known as the diffusion distance. This distance is temperature dependent because D is temperature depdendent. Hence, let us calculate the diffusion distance at T2 and T3. Given: D_0 = 1.2 x $10^{-2} m^{2/}$sec and Q = 150 kJ/mol. Also, $D = D_0 \exp\left(-Q/RT\right)$ where R is the universal gas constant.

Hence, D (T2=650K) $1.2 \times 10^{-2} \exp - 150000/(8.314 * 650)$=1.06 X 10_{-14}.and, D (T3= 600K) = 1.05 x 10_{-15}. Thus, the diffusion distance at 650 K is nearly 14 microns while it is about 4 microns at 600 K.

ΔX_0 is 0.15 (that is, 0.25-0.1) 650 K and 0.25 (that is, 0.25-0) at 600 K. Further, $X_e^\beta - X_e^\alpha$ is 0.8 (that is, 0.9-0.1) at 650 K, and is 1.0 (that is, 1.-0.) at 600 K.

Hence, at 650 K, the growth is about 2.6 microns while at 600 K, the growth is about 1.1 microns.

7. Consider the growth of two precipitates which are close to each other as shown in the schematic (Fig. 30). Can Eq. 57 be used to describe the growth of these two precipitates? Explain.

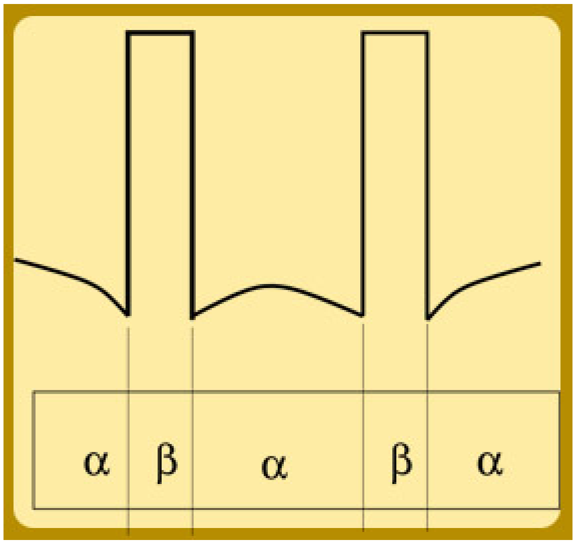

Figure 30: Two β precipitates close to each other in a supersaturated matrix growing with planar, incoherent boundaries.

Answer

No; we have derived Eq. 57 by assuming certain $\frac{dc}{dx}$. However, when two precipitates are close, their diffusion fields overlap. Because of this, the $\frac{dc}{dx}$ decreases much more rapidly then when there is only one precipitate. So, in the case where the diffusion fields overlap, the growth rate decelerates much more rapidly and hence the growth rate deviates from that given by Eq. 57.

8. Consider the growth of a β precipitate nucleated at the grain boundary of two α grains. Explain the growth of such a precipitate assuming that the solute diffuses substitutionally. Would the growth process be different if the solute diffuses interstitially?

Answer

In the case of substitutional solute, the grain boundary diffusion is relatively faster than bulk diffusion. So, from the bulk, B atoms diffuse to the grain boundary from which they diffuse along the precipitate-matrix boundary to form a lens shaped precipitate. Such rapid lengthening and thicknening of the precipitate, however, is not important in the case of interstitial solutions in which both the grain boundary and bulk diffusivities are comparable.

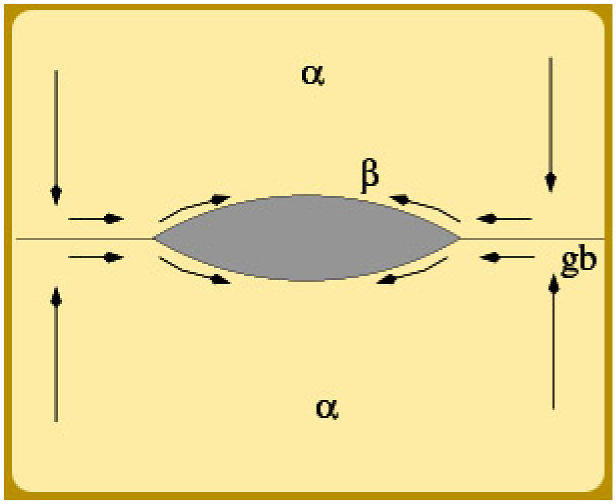

Figure 31: Short circuit diusion and the resultant precipitate morphology.