1

If copper (which has a melting point of 1085°C) homogeneously nucleates at 849°C, calculate the critical radius given values of -1.77×10^9 J/m3 and 0.200 J/m2, respectively, for the latent heat of solidification and the surface free energy.

✓ Answer

$$r^* = \frac{2\gamma T_m}{\Delta H_f \Delta T}$$
$$= -\frac{2(0.2)(1085)}{1.77 \times 10^9 (1085 - 849)}$$
$$= 1.04\ nm$$

2

Suppose that a steel of eutectoid composition (0.76 wt% C) is cooled to 500°C from 760°C in less than 0.5 s and held at this temperature.

a

How long will it take for the austenite (γ)-to-pearlite(α+Fe3C) transformation to begin? Go to 50% completion? To 100% completion?

✓ Answer

Begin: $0.8\ s$

50%: $4\ s$

100%: $10\ s$

b

Using the convention that rate = $\frac{1}{t_{0.5}}$ what is the transformation rate at this temperature?

✓ Answer

$\frac{1}{4\ s}$

3

Using the isothermal transformation diagram for a 0.45 wt% C steel alloy (Figure 11.50), determine the final microstructure (in terms of just the microconstituents present) of a small specimen that has been subjected to the following time-temperature treatments. In each case, assume that the specimen begins at 845°C, and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic (i.e. γ-iron) structure.

a

Rapidly cool to 250°C, hold for 10^3 s, then quench to room temperature.

✓ **Answer**

Martensite

b

Rapidly cool to 400°C, hold for 500 s, then quench to room temperature.

✓ **Answer**

Bainite

c

Rapidly cool to 650°C, hold at this temperature for 3 s, rapidly cool to 400°C, hold for 10 s, then quench to room temperature.

✓ **Answer**

Ferrite/α, pearlite, bainite, martensite

d

Rapidly cool to 625°C, hold for 1 s, then quench to room temperature.

✓ **Answer**

Proeutectoid ferrite, pearlite, and mertensite

4

Consider the differences between metastable and equilibrium states.

a

Martensite is a metastable phase that can be generated in steels and other systems (including other alloys, crystals, and even proteins). Describe 2 characteristics of the martensitic transformation that distinguish it from transformations that result in equilibrium microstructures.

✓ **Answer**

- There is no diffusion — as it does not change over time
- Its stucture highly depends on how it was cooled

b

In terms of heat treatment and the development of microstructure (especially metastable vs. equilibrium states), what are two major limitations of phase diagrams like the iron-iron carbide phase diagram?

✓ **Answer**

- Can't predict how long it takes for a transformation to happen
- Cannot predict when metastable phases happen

5

This week, we introduced a fourth strengthening mechanism: precipitation hardening. Compare the mechanism of strengthening involved in precipitation hardening to the mechanism underlying strain hardening (think about diffusion and dislocations).

✓ **Answer**

- In both, movement is slowed, which makes the metal stronger
- Strain hardening introduces dislocations while precipitation hardening introduces θ particles