1.   10% A heat treatment for Fe-0.5%C-2%Ni-0.5%Mo steels was carried out as follows. (a) Heated to 890°C and then quenched to 25°C, (b) immersed in liquid nitrogen for 10 minutes, and then (c) tempered at 200°C for 1 hour. What could be the dimensional changes at each step (expand or shrink at each step?) considering that phase transformations occurred during the treatments. Select an answer from the following and **EXPLAIN** your results.

(1) expand, expand again, and expand again   (2) expand, expand again, then shrink

(3) expand, shrink, and shrink again   (4) expand, shrink, then expand

(5) shrink, expand, and expand again   (6) shrink, expand, then shrink

(7) shrink, shrink, and shrink again   (8) shrink, shrink, then expand

2.   10% Calculate the percent of linear change when iron transforms from ferrite to austenite at 912°C. The atomic radii of the iron atoms in ferrite and austenite at 912°C are 0.126nm and 0.129nm, respectively.

3.   10% You are asked to measure the activation energy for the volume diffusion of Mo in Fe. Describe your experimental procedure in details (including methods/instruments).

4.   10% You are asked to demonstrate the precipitation hardening experiment using Fe-C steels. (Phase diagram shown in Figure 1) (a) Specify the steel composition (b) Describe the experimental procedure of the heat treatment.
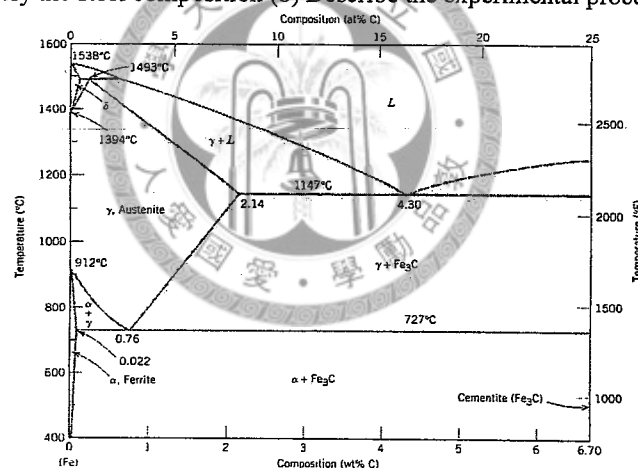
Figure 1

Figure 9.21 The iron–iron carbide phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

5. 10% A rapidly cooled Cu-5%Zn was re-heated. The thermal analysis indicated that a small amount of liquid started to form at 1060°C, which was about 5°C lower than the solidus line shown in the Cu-Zn phase diagram. Why?

6. 10% (a) Why the grain growth stopped when a Fe-0.5vol%Al$_2$O$_3$ oxide-dispersed composite (alumina particles had an average diameter of 0.5 μm) wire was annealed to the stage where most grain boundaries were perpendicular to the surface of the wire? (b) In the case of big plates, the grains in the center portion also stopped growing and reached a limiting grain size. Why?

7. 10% A gas storage tank is made of 0.1m thick steel plates. The steel plate is under a tensile stress of 250MPa. You have an x-ray detector and the smallest crack length that can be detected is 0.01m. Is it safe to use 1040 carbon steels with a tensile strength of 260MPa and a fracture toughness of 55MPa m$^{0.5}$? If you don't think so, explain why?

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8. 10% You are asked to inspect a single crystal Si ingot that is used for IC production. What type of x-ray instrument and method will you use? Describe the method and explain why other x-ray instruments are not favored.

9. 6% Construct a stereographic projection of a cubic crystal and show one closed packed plane and one closed packed direction for a bcc structure material.

10. 7% A continuous cooling transformation (CCT) curve is usually a good guide for analyzing the microstructure of a steel. Why the typical curve has a C shape as shown below (Figure 2)? Explain.
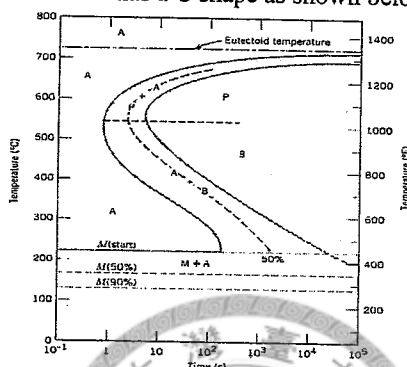
Figure 2

11. 7% Write down all invariant reactions (specify the phases involved and the approximate temperature and composition) for the Cu-Zn phase diagram shown in Figure 3.
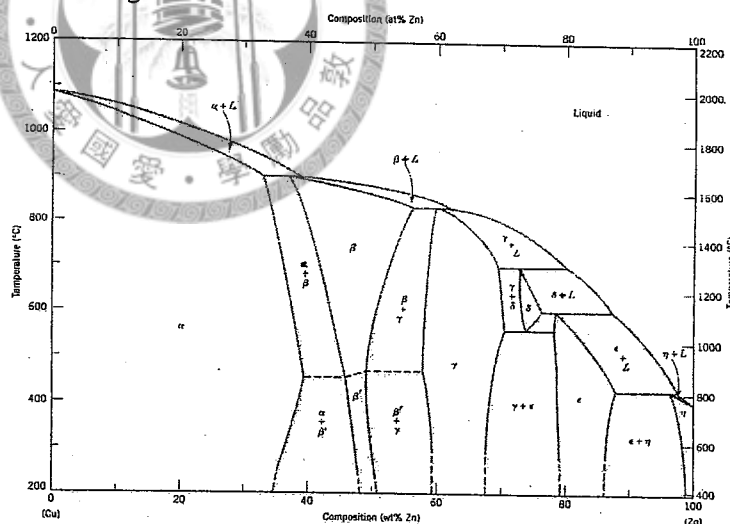
Figure 3

FIGURE 9.17 The copper-zinc phase diagram. [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 2, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]