

9.21 Yes, it is possible to have a Cu-Ag alloy of composition 20 wt% Ag-80 wt% Cu which consists of mass fractions $W_\alpha = 0.80$ and $W_L = 0.20$. Using the appropriate phase diagram, Figure 9.7, by trial and error with a ruler, the tie-line segments within the $\alpha + L$ phase region are proportioned such that

$$W_\alpha = 0.8 = \frac{C_L - C_0}{C_L - C_\alpha}$$

for $C_0 = 20$ wt% Ag. This occurs at about 800°C .

Development of Microstructure in Isomorphous Alloys

9.25 (a) Coring is the phenomenon whereby concentration gradients exist across grains in polycrystalline alloys, with higher concentrations of the component having the lower melting temperature at the grain boundaries. It occurs, during solidification, as a consequence of cooling rates that are too rapid to allow for the maintenance of the equilibrium composition of the solid phase.

(b) One undesirable consequence of a cored structure is that, upon heating, the grain boundary regions will melt first and at a temperature below the equilibrium phase boundary from the phase diagram; this melting results in a loss in mechanical integrity of the alloy.

9.32 (a) This portion of the problem asks that we determine the mass fractions of α and β phases for an 80 wt% Sn-20 wt% Pb alloy (at 180°C). In order to do this it is necessary to employ the lever rule using a tie line that extends entirely across the $\alpha + \beta$ phase field. From Figure 9.8 and at 180°C, $C_\alpha = 18.3$ wt% Sn, $C_\beta = 97.8$ wt% Sn, and $C_{\text{eutectic}} = 61.9$ wt% Sn. Therefore, the two lever-rule expressions are as follows:

$$W_\alpha = \frac{C_\beta - C_0}{C_\beta - C_\alpha} = \frac{97.8 - 80}{97.8 - 18.3} = 0.224$$

$$W_\beta = \frac{C_0 - C_\alpha}{C_\beta - C_\alpha} = \frac{80 - 18.3}{97.8 - 18.3} = 0.776$$

(b) Now it is necessary to determine the mass fractions of primary β and eutectic microconstituents for this same alloy. This requires that we utilize the lever rule and a tie line that extends from the maximum solubility of Pb in the β phase at 180°C (i.e., 97.8 wt% Sn) to the eutectic composition (61.9 wt% Sn). Thus

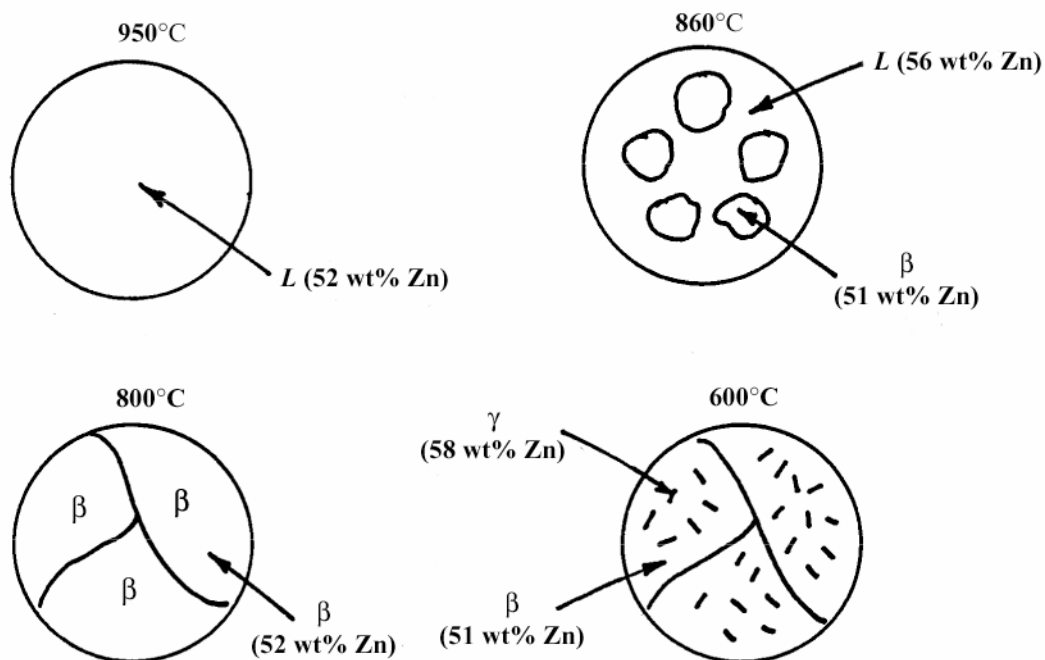
$$W_{\beta'} = \frac{C_0 - C_{\text{eutectic}}}{C_\beta - C_{\text{eutectic}}} = \frac{80.0 - 61.9}{97.8 - 61.9} = 0.504$$

$$W_e = \frac{C_\beta - C_0}{C_\beta - C_{\text{eutectic}}} = \frac{97.8 - 80.0}{97.8 - 61.9} = 0.496$$

(c) And, finally, we are asked to compute the mass fraction of eutectic β , $W_{e\beta}$. This quantity is simply the difference between the mass fractions of total β and primary β as

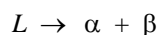
$$W_{e\beta} = W_\beta - W_{\beta'} = 0.776 - 0.504 = 0.272$$

9.37 Schematic sketches of the microstructures that would be observed for a 52 wt% Zn-48 wt% Cu alloy at temperatures of 950°C, 860°C, 800°C, and 600°C are shown below. The phase compositions are also indicated. (Note: it was necessary to use the Cu-Zn phase diagram, Figure 9.19, in constructing these sketches.)

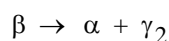


9.43 In this problem we are asked to specify temperature-composition points for all eutectics, eutectoids, peritectics, and congruent phase transformations for a portion of the aluminum-copper phase diagram (Figure 9.37).

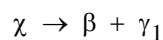
There is one eutectic on this phase diagram, which exists at 8.3 wt% Al-91.7 wt% Cu and 1036°C. Its reaction upon cooling is



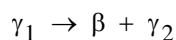
There are four eutectoids for this system. One exists at 11.8 wt% Al-88.2 wt% Cu and 565°C. This reaction upon cooling is



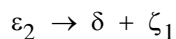
Another eutectoid exists at 15.4 wt% Al-84.6 wt% Cu and 964°C. For cooling the reaction is



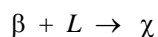
A third eutectoid exists at 15.5 wt% Al-84.5 wt% Cu and 786°C. For cooling the reaction is



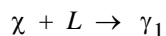
The other eutectoid exists at 23.5 wt% Al-76.5 wt% Cu and 560°C. For cooling the reaction is



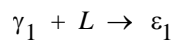
There are four peritectics on this phase diagram. One exists at 15.3 wt% Al-84.7 wt% Cu and 1037°C. The reaction upon cooling is



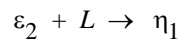
Another peritectic exists at 17 wt% Al-83 wt% Cu and 1021°C. Its cooling reaction is



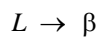
Another peritectic exists at 20.5 wt% Al-79.5 wt% Cu and 961°C. The reaction upon cooling is



Another peritectic exists at 28.4 wt% Al-71.6 wt% Cu and 626°C. The reaction upon cooling is



There is a single congruent melting point that exists at 12.5 wt% Al-87.5 wt% Cu and 1049°C. The reaction upon cooling is



9.47 (a) A “hypoeutectoid” steel has a carbon concentration less than the eutectoid; on the other hand, a “hypereutectoid” steel has a carbon content greater than the eutectoid.

(b) For a hypoeutectoid steel, the proeutectoid ferrite is a microconstituent that formed above the eutectoid temperature. The eutectoid ferrite is one of the constituents of pearlite that formed at a temperature below the eutectoid. The carbon concentration for both ferrites is 0.022 wt% C.

9.50 This problem asks us to consider various aspects of 3.5 kg of austenite containing 0.95 wt% C that is cooled to below the eutectoid.

(a) The proeutectoid phase will be Fe_3C since 0.95 wt% C is greater than the eutectoid composition (0.76 wt% C).

(b) For this portion of the problem, we are asked to determine how much total ferrite and cementite form. Application of the appropriate lever rule expression yields

$$W_{\alpha} = \frac{C_{\text{Fe}_3\text{C}} - C_0}{C_{\text{Fe}_3\text{C}} - C_{\alpha}} = \frac{6.70 - 0.95}{6.70 - 0.022} = 0.86$$

which, when multiplied by the total mass of the alloy, gives $(0.86)(3.5 \text{ kg}) = 3.01 \text{ kg}$ of total ferrite.

Similarly, for total cementite,

$$W_{\text{Fe}_3\text{C}} = \frac{C_0 - C_{\alpha}}{C_{\text{Fe}_3\text{C}} - C_{\alpha}} = \frac{0.95 - 0.022}{6.70 - 0.022} = 0.14$$

And the mass of total cementite that forms is $(0.14)(3.5 \text{ kg}) = 0.49 \text{ kg}$.

(c) Now we are asked to calculate how much pearlite and the proeutectoid phase (cementite) form. Applying Equation 9.22, in which $C_1' = 0.95 \text{ wt\% C}$

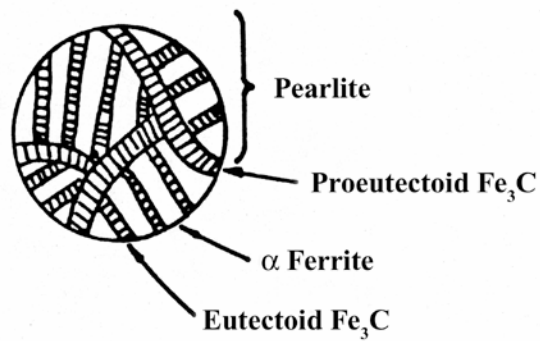
$$W_{\text{P}} = \frac{6.70 - C_1'}{6.70 - 0.76} = \frac{6.70 - 0.95}{6.70 - 0.76} = 0.97$$

which corresponds to a mass of $(0.97)(3.5 \text{ kg}) = 3.4 \text{ kg}$. Likewise, from Equation 9.23

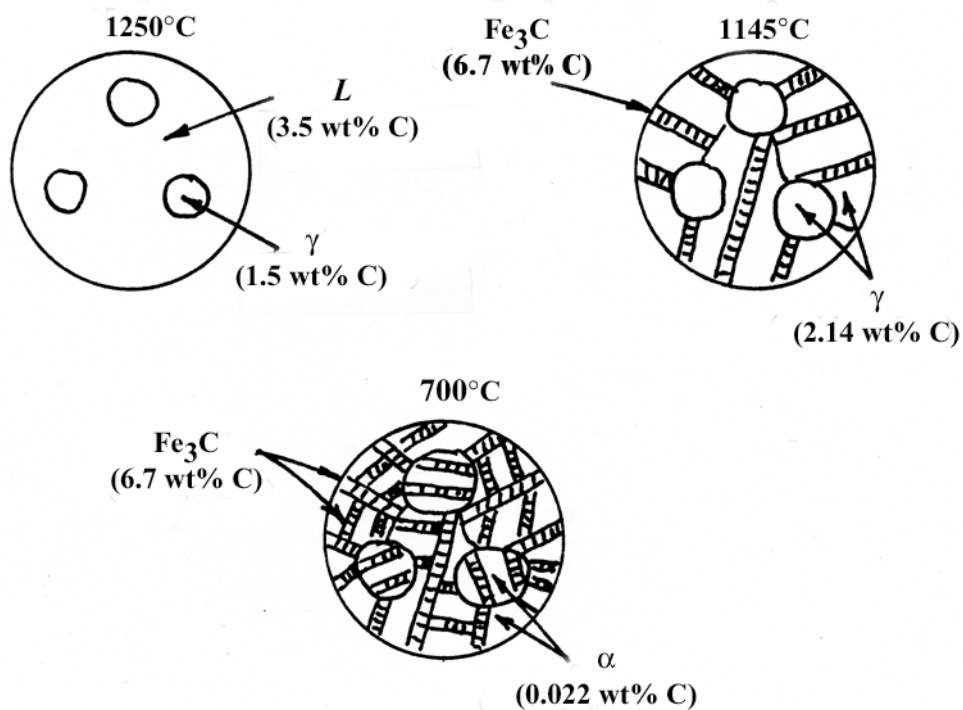
$$W_{\text{Fe}_3\text{C}'} = \frac{C_1' - 0.76}{5.94} = \frac{0.95 - 0.76}{5.94} = 0.03$$

which is equivalent to $(0.03)(3.5 \text{ kg}) = 0.11 \text{ kg}$ of the total 3.5 kg mass.

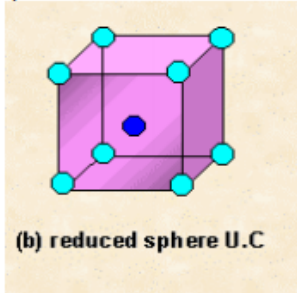
(d) Schematically, the microstructure would appear as:



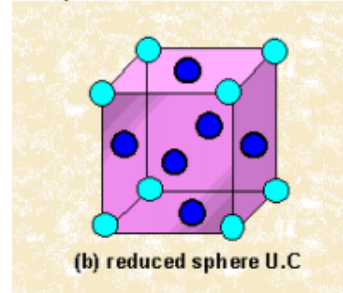
9.63 Schematic microstructures for the iron-carbon alloy of composition 3 wt% C-97 wt% Fe and at temperatures of 1250°C, 1145°C, and 700°C are shown below; approximate phase compositions are also indicated. (Note: it was necessary to use the Fe-Fe₃C phase diagram, Figure 9.24, in constructing these sketches.)



- a) Non-alloyed iron may have two different crystal structures, depending on the surrounding temperature. At room temperature (up to 912 °C) iron is present in BCC structure. From 912 °C up to 1394 °C it is present in FCC structure. From 1394 °C up to the melting point (1538 °C) it is again present in BCC structure. The two structures are sketched below. The packing factor for BCC is a little smaller than in the FCC. A transformation from one crystal structure to the other for the same element is called polymorphism or allotropy. It is often possible to observe changes in the physical properties for a material which undergoes the allotropic transformations.



Romsentrert kubisk struktur (BCC)



Flatesentrert kubisk struktur (FCC)

- b) The lattice constant “a” is the same as the length of the FCC unit cell edge. From the geometric consideration of one of the cell sides it is possible to calculate the lattice constant using Pythagoras equation: $a^2 + a^2 = (R+2R+R)^2$ solving for $a = 2(2)^{1/2}R$. For aluminium it means that the lattice constant $a = 2(2)^{1/2} 0,1431 = 0,4047$ nm.
- c) The highest solubility could be found in the austenite FCC structure because the FCC interstitial positions are larger than in the BCC structure (octahedral vs. tetrahedral holes). Consequently the lattice expansion as a consequence of carbon introduction into these positions will be the smallest, something which energetically prefer solution of carbon in FCC structure to those in BCC structure. The maximum solubility of carbon in iron is 2,14 weight % at 1147 °C.