Interpretation of Phase Diagrams

9.6 *Cite the phases that are present and the phase compositions for the following alloys:*

(a) 15 wt% Sn–85 wt% Pb at 100°C

(b) 25 wt% Pb–75 wt% Mg at 425°C

(c) 55 wt% Zn–45 wt% Cu at 600°C

Solution

(a) For an alloy composed of 15 wt% Sn-85 wt% Pb and at 100°C, from Figure 9.8, α and β phases are present, and using a tie line constructed at this temperature, the compositions of these phases are determined as follows:

$$C_\alpha = 5 \text{ wt\% Sn-95 wt\% Pb}$$

$$C_\beta = 98 \text{ wt\% Sn-2 wt\% Pb}$$

(b) For an alloy composed of 25 wt% Pb-75 wt% Mg and at 425°C, from Figure 9.20, only the α phase is present; its composition is 25 wt% Pb-75 wt% Mg.

(c) For an alloy composed of 55 wt% Zn-45 wt% Cu and at 600°C, from Figure 9.19, β and γ phases are present, and using a tie line constructed at this temperature, the compositions of these phases are determined as follows:

$$C_\beta = 51 \text{ wt\% Zn-49 wt\% Cu}$$

$$C_\gamma = 58 \text{ wt\% Zn-42 wt\% Cu}$$

9.8 *A 50 wt% Ni–50 wt% Cu alloy is slowly cooled from 1400°C to 1200°C.*

(a) At what temperature does the first solid phase form?

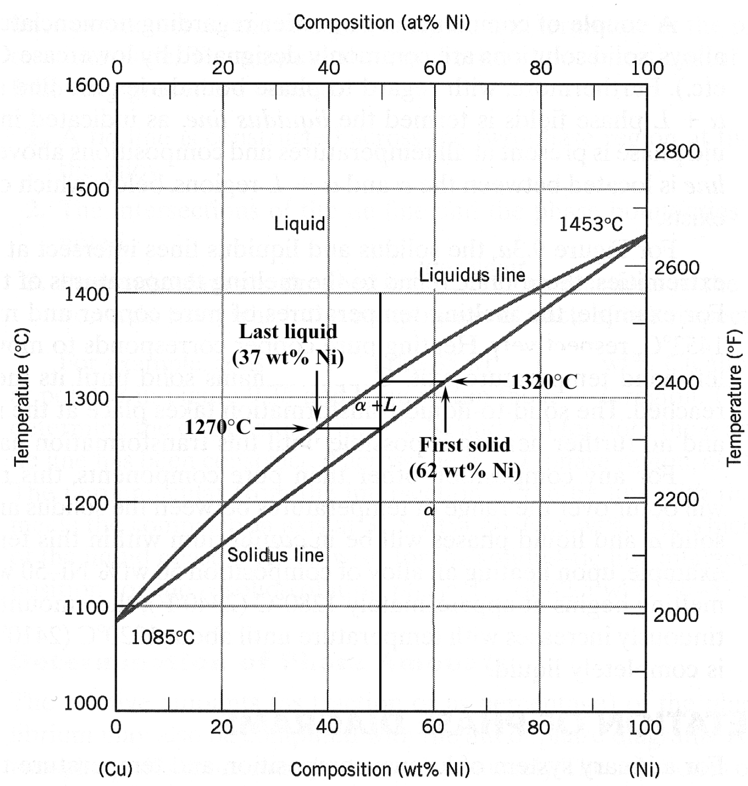
(b) What is the composition of this solid phase?

(c) At what temperature does the liquid solidify?

(d) What is the composition of this last remaining liquid phase?

Solution

Shown below is the Cu-Ni phase diagram (Figure 10.3a) and a vertical line constructed at a composition of 50 wt% Ni-50 wt% Cu.



(a)

(a) The first solid phase forms at the temperature at which a vertical line at this composition intersects the L–($\alpha + L$) phase boundary--i.e., at about 1320°C.

(b) The composition of this solid phase corresponds to the intersection with the L–($\alpha + L$) phase boundary, of a tie line constructed across the $\alpha + L$ phase region at 1320°C--i.e., C_α = 62 wt% Ni-38 wt% Cu.

(c) Complete solidification of the alloy occurs at the intersection of this same vertical line at 50 wt% Ni with the ($\alpha + L$)–α phase boundary—i.e., at about 1270°C.

(d) The composition of the last liquid phase remaining prior to complete solidification corresponds to the intersection with the L–($\alpha + L$) boundary, of the tie line constructed across the $\alpha + L$ phase region at 1270°C—i.e., C_L is about 37 wt% Ni-63 wt% Cu.

9.9 *Determine the relative amounts (in terms of mass fractions) of the phases for the alloys and temperatures given in Problem 9.6.*

Solution

(a) For an alloy composed of 15 wt% Sn-85 wt% Pb and at 100°C, compositions of the α and β phases are

$$C_\alpha = 5 \text{ wt\% Sn-95 wt\% Pb}$$
$$C_\beta = 98 \text{ wt\% Sn-2 wt\% Pb}$$

And, since the composition of the alloy, C_0 = 15 wt% Sn-85 wt% Pb, then, using the appropriate lever rule expressions and taking compositions in weight percent tin

$$W_\alpha = \frac{C_\beta - C_0}{C_\beta - C_\alpha} = \frac{98 - 15}{98 - 5} = 0.89$$

$$W_\beta = \frac{C_0 - C_\alpha}{C_\beta - C_\alpha} = \frac{15 - 5}{98 - 5} = 0.11$$

(b) For an alloy composed of 25 wt% Pb-75 wt% Mg and at 425°C, only the α phase is present; therefore W_α = 1.0.

(c) For an alloy composed of 55 wt% Zn-45 wt% Cu and at 600°C, compositions of the β and γ phases are

$$C_\beta = 51 \text{ wt\% Zn-49 wt\% Cu}$$
$$C_\gamma = 58 \text{ wt\% Zn-42 wt\% Cu}$$

And, since the composition of the alloy, C_0 = 55 wt% Zn-45 wt% Cu, then, using the appropriate lever rule expressions and taking compositions in weight percent zinc

$$W_\beta = \frac{C_\gamma - C_0}{C_\gamma - C_\beta} = \frac{58 - 55}{58 - 51} = 0.43$$

$$W_\gamma = \frac{C_0 - C_\beta}{C_\gamma - C_\beta} = \frac{55 - 51}{58 - 51} = 0.57$$

9.12 *A 40 wt% Pb–60 wt% Mg alloy is heated to a temperature within the α + liquid-phase region. If the mass fraction of each phase is 0.5, then estimate:*

(a) the temperature of the alloy

(b) the compositions of the two phases in weight percent

(c) the compositions of the two phases in atom percent

Solution

(a) We are given that the mass fractions of α and liquid phases are both 0.5 for a 40 wt% Pb-60 wt% Mg alloy and are asked to estimate the temperature of the alloy. Using the appropriate phase diagram, Figure 9.20, by trial and error with a ruler, a tie line within the α + L phase region that is divided in half for an alloy of this composition exists at about 540°C.

(b) We are now asked to determine the compositions (in weight percent) of the two phases. This is accomplished by noting the intersections of this tie line with both the solidus and liquidus lines. From these intersections, C_α = 26 wt% Pb-74 wt% Mg and C_L = 54 wt% Pb-46 wt% Mg.

(c) In order to convert these compositions to atom percent it is necessary to use Equations 4.6a and 4.6b, which include the atomic weights of lead and magnesium:

A_{Pb} = 207.2 g/mol

A_{Mg} = 24.31 g/mol

Therefore, these concentration conversions are as follows:

For the concentration of lead in the α phase, $C'_{\text{Pb}}(\alpha)$, in atom percent

$$C'_{\text{Pb}}(\alpha) = \frac{C_{\text{Pb}}(\alpha) A_{\text{Mg}}}{C_{\text{Pb}}(\alpha) A_{\text{Mg}} + C_{\text{Mg}}(\alpha) A_{\text{Pb}}} \times 100$$

$$= \frac{(26 \text{ wt\% Pb})(24.31 \text{ g/mol})}{(26 \text{ wt\% Pb})(24.31 \text{ g/mol}) + (74 \text{ wt\% Mg})(207.2 \text{ g/mol})} \times 100$$

$$= 4.0 \text{ at\%}$$

The concentration of magnesium (in atom percent) in the α phase, is determined as follows:

$$C'_{\text{Mg}}(\alpha) = \frac{C_{\text{Mg}}(\alpha) A_{\text{Pb}}}{C_{\text{Pb}}(\alpha) A_{\text{Mg}} + C_{\text{Mg}}(\alpha) A_{\text{Pb}}} \times 100$$

Binary Eutectic Systems

9.18 *A 60 wt% Pb–40 wt% Mg alloy is rapidly quenched to room temperature from an elevated temperature in such a way that the high-temperature microstructure is preserved. This microstructure is found to consist of the α phase and Mg_2Pb, having respective mass fractions of 0.42 and 0.58. Determine the approximate temperature from which the alloy was quenched.*

Solution

We are asked to determine the approximate temperature from which a 60 wt% Pb-40 wt% Mg alloy was quenched, given the mass fractions of α and Mg_2Pb phases. Using Figure 9.20, we can write a lever-rule expression for the mass fraction of the α phase as

$$W_\alpha = 0.42 = \frac{C_{Mg_2Pb} - C_0}{C_{Mg_2Pb} - C_\alpha}$$

The value of C_0 is stated as 60 wt% Pb-40 wt% Mg, and C_{Mg_2Pb} is 81 wt% Pb-19 wt% Mg, which is independent of temperature (Figure 9.20); thus, incorporation of these values for C_0 and C_{Mg_2Pb} into the above equation yields

$$0.42 = \frac{81 - 60}{81 - C_\alpha}$$

and solving for C_α leads to the following:

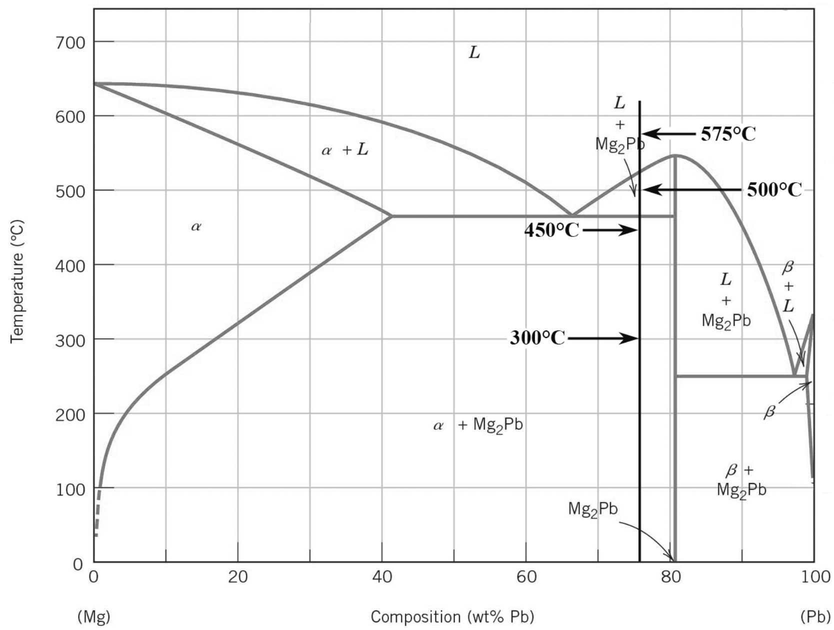
$$C_\alpha = 31.0 \text{ wt\% Pb}$$

From Figure 9.20, the temperature at which the α–(α + Mg_2Pb) phase boundary has a value of 31.0 wt% Pb is about 400°C.

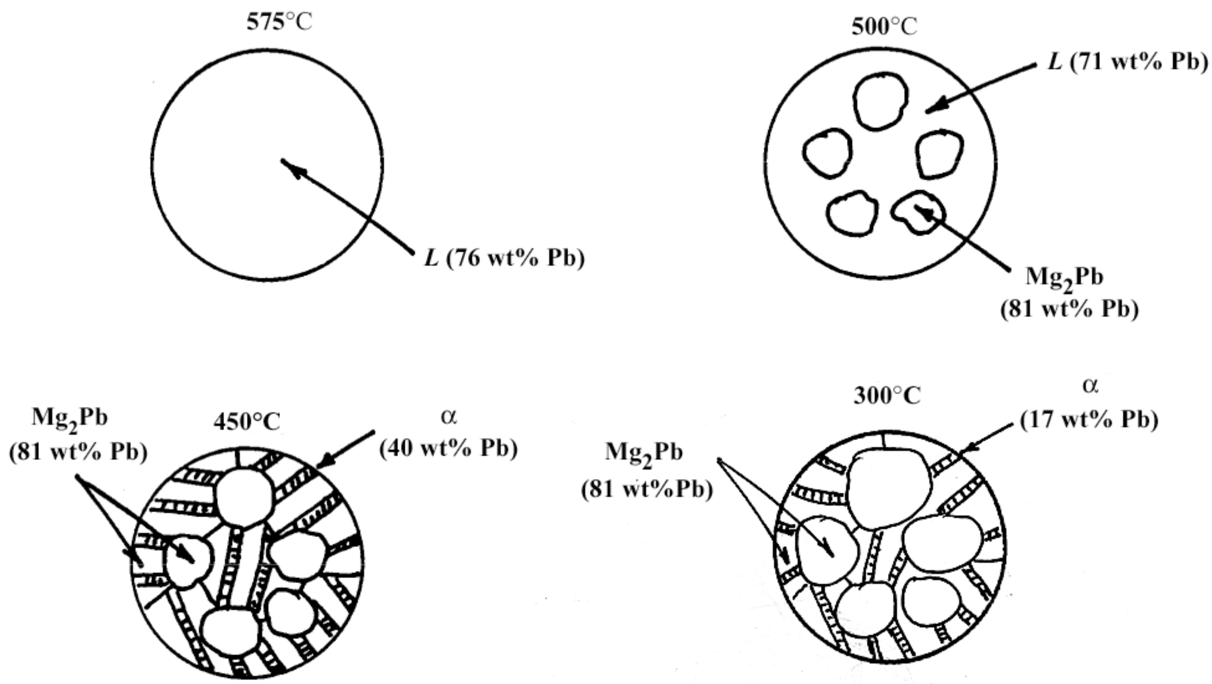
9.24 *For a 76 wt% Pb–24 wt% Mg alloy, make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 575°C, 500°C, 450°C, and 300°C. Label all phases and indicate their approximate compositions.*

Solution

The illustration below is the Mg-Pb phase diagram (Figure 9.20). A vertical line at a composition of 76 wt% Pb-24 wt% Mg has been drawn, and, in addition, horizontal arrows at the four temperatures called for in the problem statement (i.e., 575°C, 500°C, 450°C, and 300°C).



On the basis of the locations of the four temperature-composition points, schematic sketches of the four respective microstructures along with phase compositions are represented as follows:



575°C
L (76 wt% Pb)
500°C
L (71 wt% Pb)
Mg_2Pb
(81 wt% Pb)
Mg_2Pb
(81 wt% Pb)
450°C
α
(40 wt% Pb)
300°C
α
(17 wt% Pb)
Mg_2Pb
(81 wt%Pb)