Question 1:

a) What is the difference between a phase and a micro constituent?
b) What is the limitation of phase diagram?

Solution:

(a) A "phase" is a homogeneous portion of the system having uniform physical and chemical characteristics, whereas a "micro constituent" is an identifiable element of the microstructure (that may consist of more than one phase).

(b) Phase diagram does not show the effect of cooling rate. It gives the expected phases in an alloy at a given temperature under equilibrium condition.

Question 2:

i) Is it possible to have a copper-nickel alloy that, at equilibrium, consists of a liquid phase of composition 20 wt% Ni-80 wt% Cu and also an α phase of composition 37 wt% Ni-63 wt% Cu? If so, what will be the approximate temperature of the alloy? If this is not possible, explain why.

ii) Briefly explain why, upon solidification, an alloy of eutectic composition forms a microstructure consisting of alternating layers of the two solid phases.

Solution:

i) It is **not possible** to have a Cu-Ni alloy, which at equilibrium, consists of a liquid phase of composition 20 wt% Ni-80 wt% Cu and an α phase of composition 37 wt% Ni-63 wt% Cu. From the Cu-Ni phase diagram, a single tie line does not exist within the α + **L** region that intersects the phase boundaries at the given compositions. At 20 wt% Ni, the **L**-(α + **L**) phase boundary is at about 1200 °C, whereas at 37 wt% Ni the (**L** + α)- α phase boundary is at about 1230 °C.

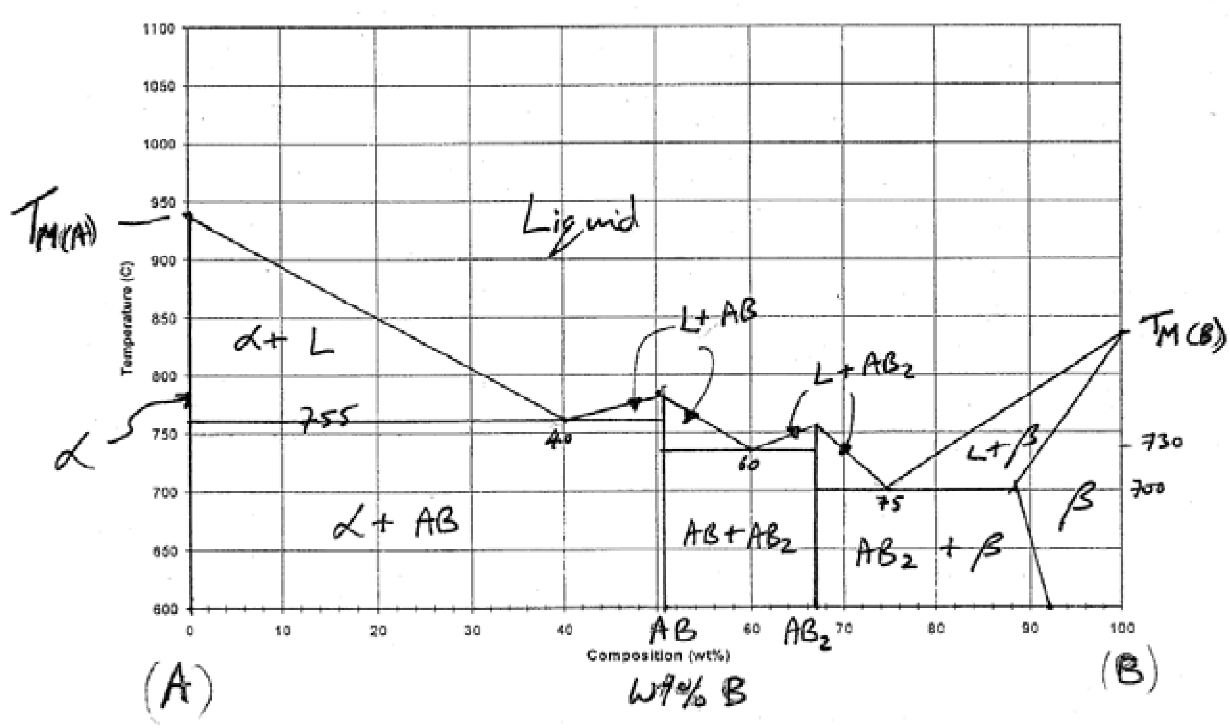
ii) Upon solidification, an alloy of eutectic composition forms a microstructure consisting of alternating layers of the two solid phases because during the solidification atomic diffusion must occur, and with this layered configuration the diffusion path length for the atoms is a minimum.

Question 3:

Construct the hypothetical phase diagram for metals A and B between temperatures of 600°C and 1000°C given the following information (assume all phase boundaries are straight lines):

- The melting temperature of metal A is 940°C.
- The solubility of B in A is negligible at all temperatures.
- The melting temperature of metal B is 830°C.
- The maximum solubility of A in B is 12 wt% A, which occurs at 700°C.
- At 600°C, the solubility of A in B is 8 wt% A. One eutectic occurs at 700°C and 75 wt% B -25 wt%A.
- A second eutectic occurs at 730°C and 60 wt% B-40 wt% A.
- A third eutectic occurs at 755°C and 40 wt% B-60 wt% A.
- One congruent melting point occurs at 780°C and 51 wt% B-49 wt% A.
- A second congruent melting point occurs at 755°C and 67 wt% B-33 wt% A.
- The intermetallic compound AB exists at 51 wt% B-49 wt% A.
- The intermetallic compound AB_2 exists at 67 wt% B-33 wt% A.

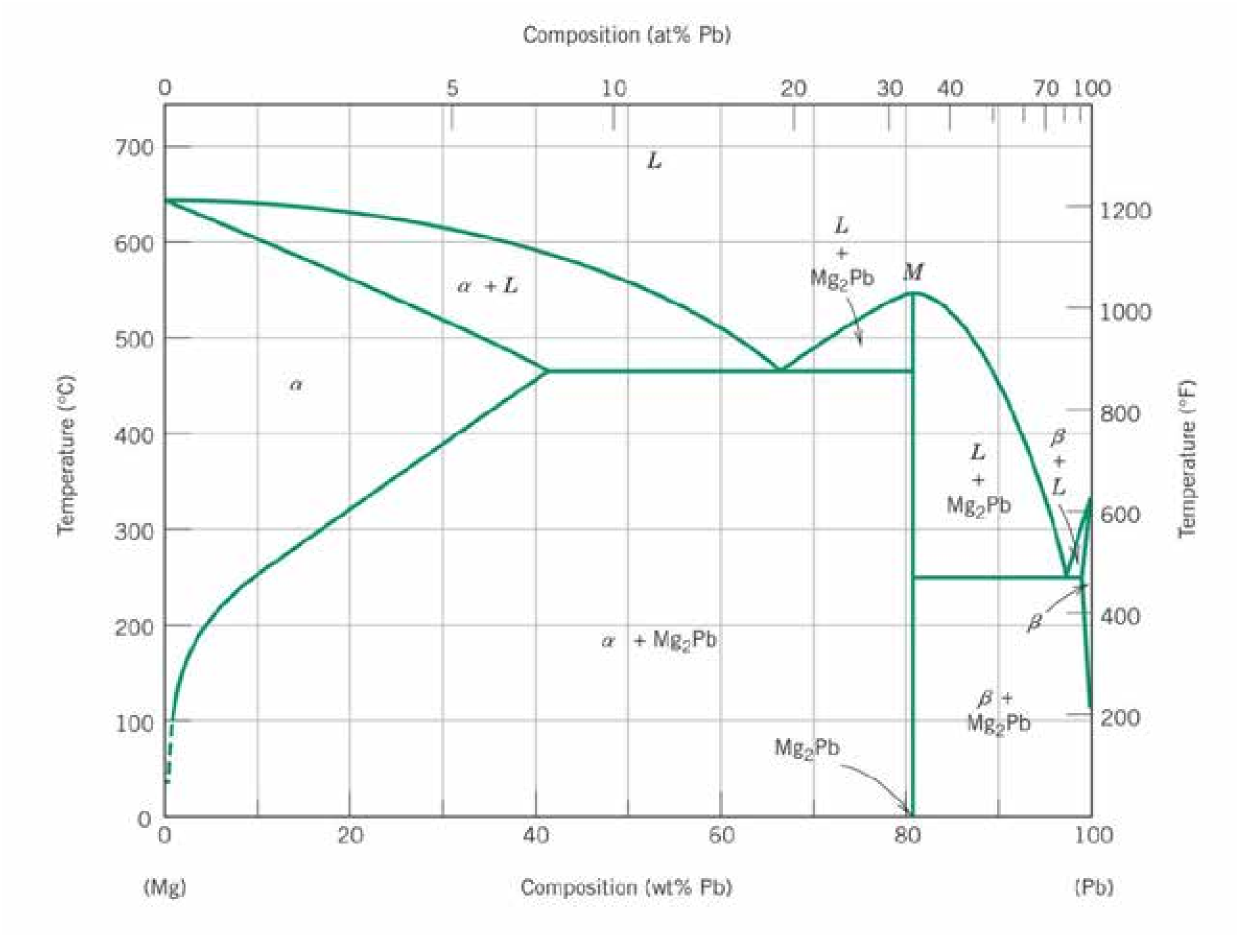
Solution:



Question 4:

Cite the phases that are present and the phase composition for the following alloy.

(1) 37 lbm Pb and 6.5 lbm Mg at 400 °C



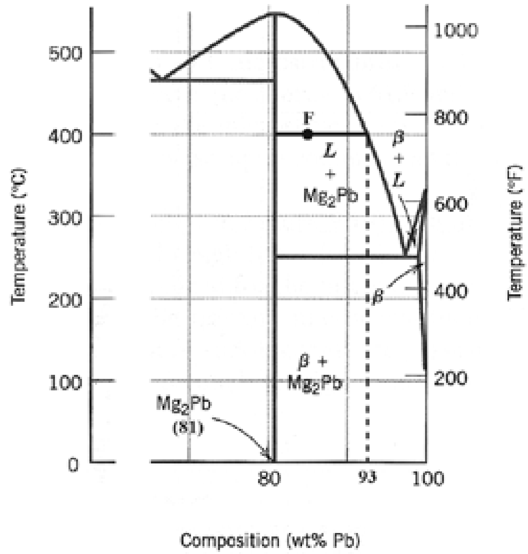
Solution:

For an alloy composed of 37 lb_m Pb and 6.5 lb_m Mg and at 400°C, we must first determine the Pb and Mg concentrations, as

$$C_{Pb} = \frac{37\ lb_m}{37\ lb_m + 6.5\ lb_m} \times 100 = 85\ wt\%$$

$$C_{Mg} = \frac{6.5\ lb_m}{37\ lb_m + 6.5\ lb_m} \times 100 = 15\ wt\%$$

That portion of the Mg-Pb phase diagram (Figure 9.20) that pertains to this problem is shown below; the point labeled "F" represents the 85 wt% Pb-15 wt% Mg composition at 400°C.



As may be noted, point F lies within the *L* + Mg_2Pb phase field. A tie line has been constructed at 400°C; it intersects the vertical line at 81 wt% Pb, which corresponds to the composition of Mg_2Pb. Furthermore, the tie line intersection with the *L* + Mg_2Pb-*L* phase boundary is at 93 wt% Pb, which is the composition of the liquid phase. Thus, the phase compositions are as follows:

$$C_{Mg_2Pb} = 81 \text{ wt\% Pb-19 wt\% Mg}$$

$$C_L = 93 \text{ wt\% Pb-7 wt\% Mg}$$

Question 5:

A 50 wt% Pb-50 wt% Mg alloy is slowly cooled from 700°C (1290°F) to 400°C (750°F). Use Magnesium-Lead Phase Diagram from Question 2.

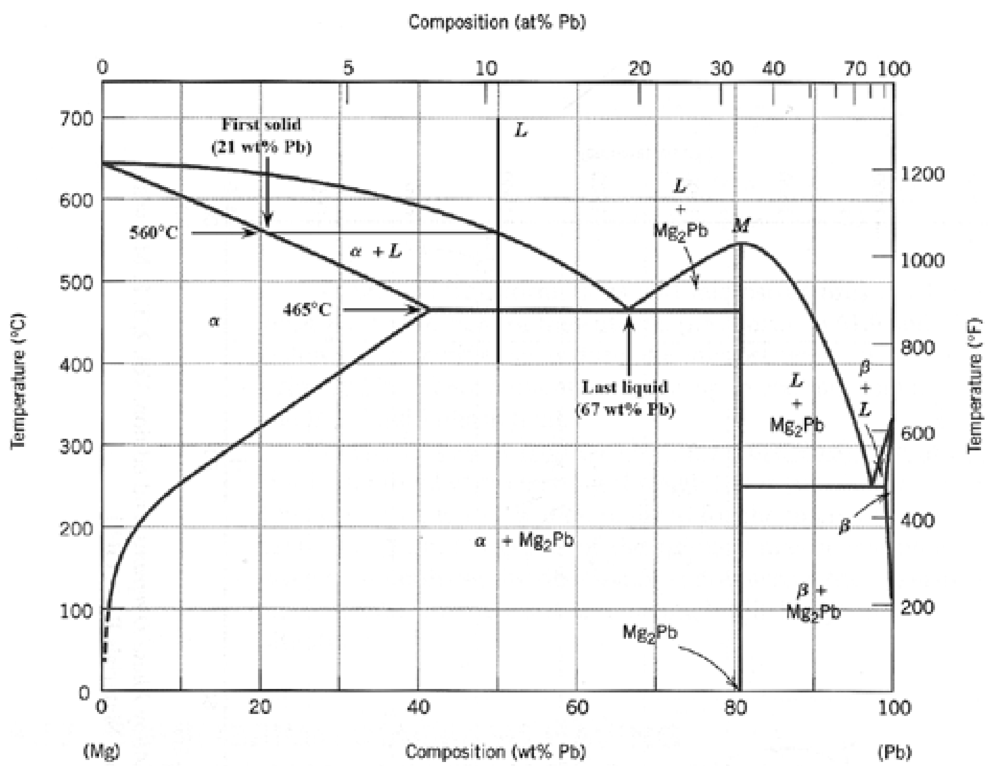
(a) At what temperature does the first solid phase form?

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

(c) At what temperature does the liquid solidify?

Solution:

Shown below is the Mg-Pb phase diagram (Figure 9.20) and a vertical line constructed at a composition of 50 wt% Pb-50 wt% Mg.



(a) Upon cooling from 700°C, the first solid phase forms at the temperature at which a vertical line at this composition intersects the *L*-(a + *L*) phase boundary--i.e., about 560°C;

(b) The composition of this solid phase corresponds to the intersection with the a-(a + *L*) phase boundary, of a tie line constructed across the a + *L* phase region at 560°C--i.e., 21 wt% Pb-79 wt% Mg;

(c) Complete solidification of the alloy occurs at the intersection of this same vertical line at 50 wt% Pb with the eutectic isotherm--i.e., about 465°C;

Question 6:

Consider 1.0 kg of austenite containing 1.15 wt% C, cooled to below 727°C (1341°F).

(a) How many kilograms each of total ferrite and cementite form?

(b) How many kilograms each of pearlite and the proeutectoid phase form?

(c) Schematically sketch and label the resulting microstructure.

Solution:

The proeutectoid phase will be Fe_3C since 1.15 wt% C is greater than the eutectoid composition (0.76 wt% C).

(a) 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

$$W_\alpha = \frac{C_{Fe_3C} - C_0}{C_{Fe_3C} - C_\alpha} = \frac{6.70 - 1.15}{6.70 - 0.022} = 0.83$$

which, when multiplied by the total mass of the alloy (1.0 kg), gives 0.83 kg of total ferrite.

Similarly, for total cementite,

$$W_{Fe_3C} = \frac{C_0 - C_\alpha}{C_{Fe_3C} - C_\alpha} = \frac{1.15 - 0.022}{6.70 - 0.022} = 0.17$$

And the mass of total cementite that forms is (0.17)(1.0 kg) = 0.17 kg.

(b) Now we are asked to calculate how much pearlite and the proeutectoid phase (cementite) form. Applying Equation 9.22, in which $C_1' = 1.15$ wt% C

$$W_p = \frac{6.70 - C_1'}{6.70 - 0.76} = \frac{6.70 - 1.15}{6.70 - 0.76} = 0.93$$

which corresponds to a mass of 0.93 kg. Likewise, from Equation 9.23

$$W_{Fe_3C'} = \frac{C_1' - 0.76}{5.94} = \frac{1.15 - 0.76}{5.94} = 0.07$$

which is equivalent to 0.07 kg of the total 1.0 kg mass.

(c) Schematically, the microstructure would appear as: