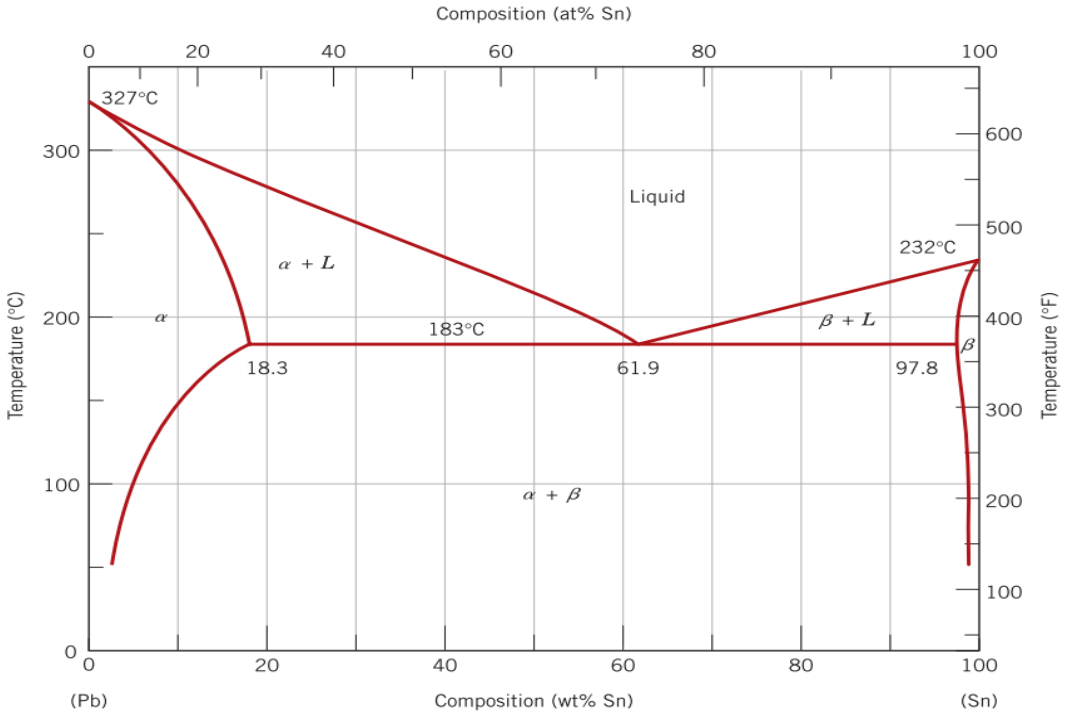
Note: These questions will be discussed in the tutorial sessions on November 7.

Question 1:

(a) Cite the phases that are present and the phase compositions for the following alloy: 4.5 mol Sn and 0.45 mol Pb at 200°C (390°F)

(b) Determine the relative amounts (in terms of mass fractions) of the phases for the alloys and temperatures given in part (a).



Solution:

a) For an alloy composed of 4.5 mol Sn and 0.45 mol Pb and at 200°C, it is first necessary to determine the Sn and Pb concentrations, which we will do in weight percent as follows:

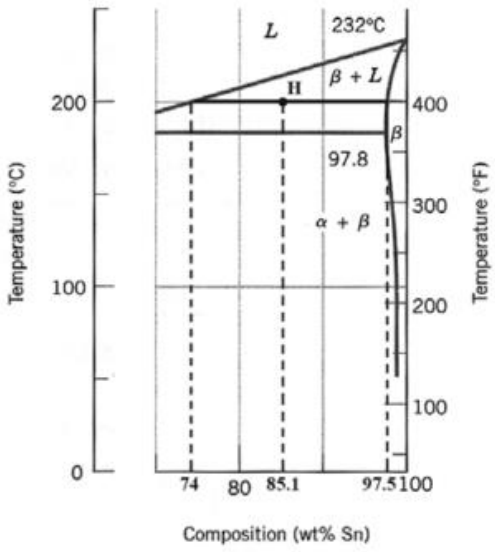
$m_{Sn'} = n_{m\,Sn} \times A_{Sn} = (4.5\ mol)(118.71\ g/mol) = 534.2\ g$

$m_{Pb}' = n_{mPb} \times A_{Pb} = (0.45\ mol)(207.2\ g/mol) = 93.2\ g$

$C_{Sn} = 534.2\ g/(534.2\ g + 93.2\ g) \times 100 = 85.1\ wt\%$

$C_{Pb} = 93.2\ g/(534.2\ g + 93.2\ g) \times 100 = 14.9\ wt\%$

That portion of the Pb-Sn phase diagram (Figure 9.8) that pertains to this problem is shown below; the point labeled "H" represents the 85.1 wt% Sn-14.9 wt% Pb composition at 200°C.

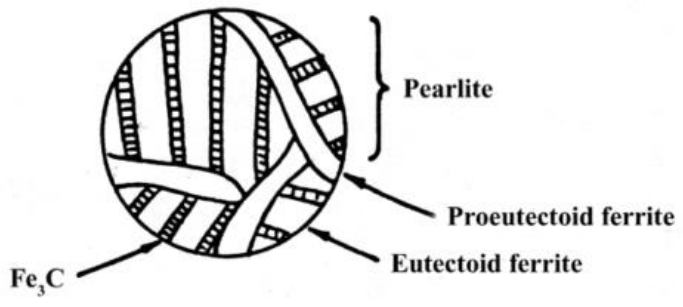


As may be noted, point H lies within the β + L phase field. A tie line has been constructed at 200°C; its intersection with the L–β + L phase boundary is at 74 wt% Sn, which corresponds to the composition of the L phase. Similarly, the tie-line intersection with the β + L–β phase boundary occurs at 97.5 wt% Sn, which is the composition of the β phase. Thus, the phase compositions are as follows:

C_β = 97.5 wt% Sn-2.5 wt% Pb
C_L = 74 wt% Sn-26 wt% Pb
(b)From part (a), β and L phases are present at 200°C. Furthermore, the compositions of the phases, as determined from the tie line.
In as much as the composition of the alloy C_0 = 85.1 wt% Sn, application of the appropriate lever rule expressions (for compositions in weight percent lead) leads to
$W_\beta = (C_0 - C_L)/(C_\beta - C_L) = (85.1 - 74)/(97.5 - 74) = 0.47$
$W_L = (C_\beta - C_0)/(C_\beta - C_L) = (97.5 - 85.1)/(97.5 - 74) = 0.53$

Question 2:
Consider 2.5 kg of austenite containing 0.65 wt% C, cooled to below 727°C (1341°F).
(a) What is the proeutectoid phase?
(b) How many kilograms each of total ferrite and cementite form?
(c) How many kilograms each of pearlite and the proeutectoid phase form?
(d) Schematically sketch and label the resulting microstructure.

Solution
(a) Ferrite is the proeutectoid phase since 0.65 wt% C is less than 0.76 wt% C.
(b) For this portion of the problem, we are asked to determine how much total ferrite and cementite form. For ferrite, application of the appropriate lever rule expression yields
$W_\alpha = (C_{Fe3C} - C_0)/(C_{Fe3C} - C_\alpha) = (6.70 - 0.65)/(6.70 - 0.022) = 0.91$
which corresponds to (0.91)(2.5 kg) = 2.275 kg of total ferrite.
Similarly, for total cementite,
$W_{Fe3C} = (C_0 - C_\alpha)/(C_{Fe3C} - C_\alpha) = (0.65 - 0.022)/(6.70 - 0.022) = 0.09$
(0.09)(2.5 kg)=0.225kg
(c) Now consider the amounts of pearlite and proeutectoid ferrite. Using Equation 9.20
$W_p = (C_0' - 0.022)/0.74 = (0.65 - 0.022)/0.74 = 0.85$
This corresponds to (0.85)(2.5 kg) = 2.12 kg of pearlite. Also, from Equation 9.21,
$W_{\alpha'} = (0.76 - 0.65)/0.74 = 0.15$
Or, there are (0.15)(2.5 kg) = 0.38 kg of proeutectoid ferrite.
(d) Schematically, the microstructure would appear as:



Question 3:

A three-point bending test was performed on an aluminum oxide specimen having a circular cross section of radius 3.5 mm (0.14 in.); the specimen fractured at a load of 950 N (215 lbf) when the distance between the support points was 50 mm (2.0in.). Another test is to be performed on a specimen of this same material, but one that has a square cross section of 12 mm (0.47 in.) length on each edge.At what load would you expect this specimen to fracture if the support point separation is 40 mm (1.6 in.)?

Solution

For this problem, the load is given at which a circular specimen of aluminum oxide fractures when subjected to a three-point bending test; we are then are asked to determine the load at which a specimen of the same material having a square cross-section fractures. It is first necessary to compute the flexural strength of the aluminum oxide, Equation 12.7b, and then, using this value, we may calculate the value of *Ff* in Equation 12.7a. From Equation 12.7b

$$\sigma_{fs} = \frac{F_f L}{\pi R^3}$$

$$= \frac{(950\ \text{N})(50 \times 10^{-3}\ \text{m})}{(\pi)(3.5 \times 10^{-3}\ \text{m})^3} = 352 \times 10^6\ \text{N/m}^2 = 352\ \text{MPa} \quad (50{,}000\ \text{psi})$$

Now, solving for *Ff* from Equation 12.7a, realizing that *b* = *d* = 12 mm, yields

$$F_f = \frac{2\sigma_{fs} d^3}{3L}$$

$$= \frac{(2)(352 \times 10^6\ \text{N/m}^2)(12 \times 10^{-3}\text{m})^3}{(3)(40 \times 10^{-3}\ \text{m})} = 10{,}100\ \text{N} \quad (2165\ \text{lb}_\text{f})$$

Question 4:

The microstructure of an iron-carbon alloy consists of 11wt% proeutectoid cementite and 89wt% pearlite. Determine the carbon concentration of this alloy.

Solution:

Since the proeutectoid phase is cementite, consequently the alloy is hypereutectoid. For a hypereutectoid alloy using equation 9.23:

$$W_{Fe_3C} = \frac{C_1' - 0.76}{5.94} = 0.11 \Rightarrow C_1' = 1.41\ wt\%\ C$$

Question 5:

On the basis of ionic charge and ionic radii, predict crystal structures for the following materials, justifying your selections:

(a) MnS

(b) KBr

Solution:

(a) For MnS, using the data from table 12.3:

$$\frac{r_{Mn^{2+}}}{r_{S^{2-}}} = \frac{0.067\ nm}{0.184\ nm} = 0.364$$

Now, from Table 12.2, the coordination number for each cation (Mn^{2+}) is four. There is one anion per cation which means the coordination number for anion is also four. Thus using Table 12.4, the predicted crystal structure is zinc blende.

(b) For KBr, using the data from table 12.3:

$$\frac{r_{K^+}}{r_{Br^-}} = \frac{0.138\ nm}{0.196\ nm} = 0.704$$

Now, from Table 12.2, the coordination number for each cation (K^+) is six. There is one anion per cation which means the coordination number for anion is also six. Thus using Table 12.4, the predicted crystal structure is sodium chloride.