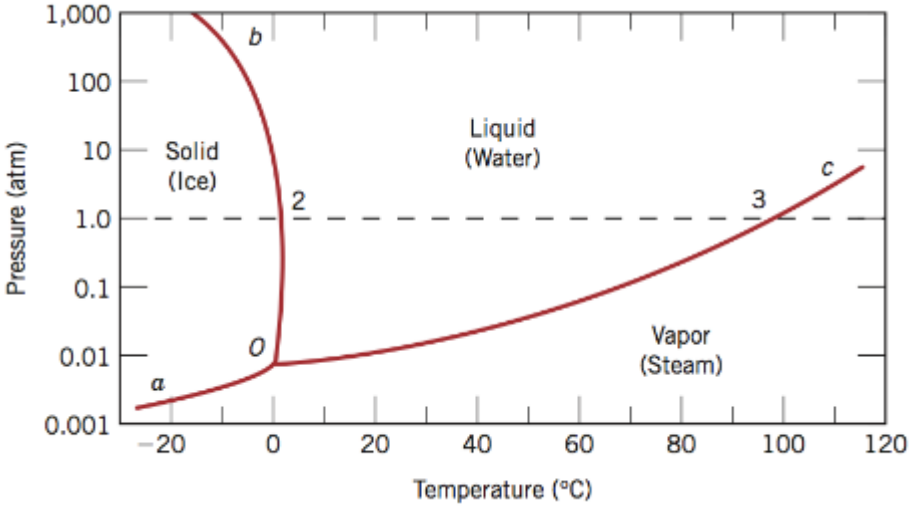
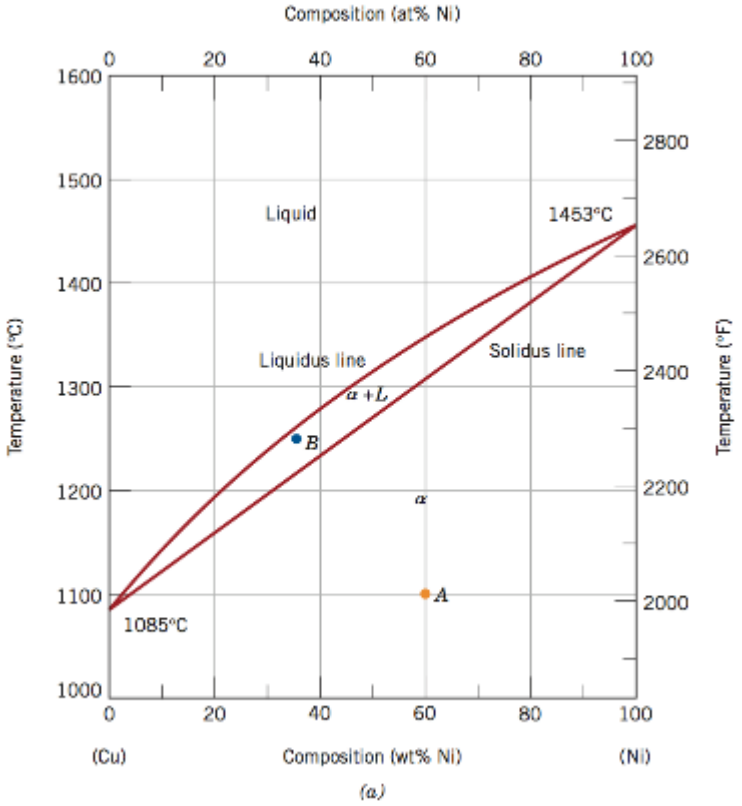
- **Alloy** is a metallic substance that is composed of two or more elements.
- **Components** are pure metals and/or compounds of which an alloy is composed.
- A **phase** may be defined as a homogeneous portion of a system of alloy.
- There are three externally controllable parameters that will affect phase structure:

1- temperature -2- pressure -3-composition

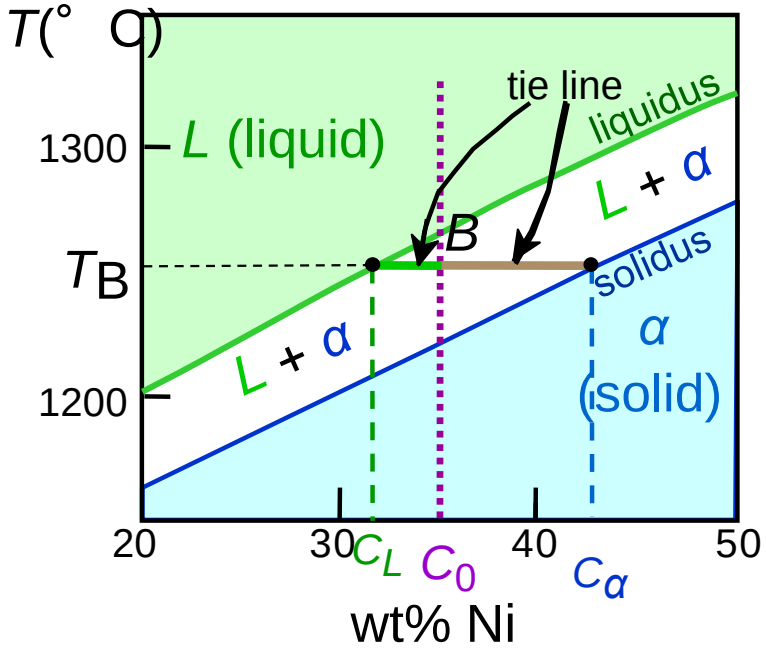
One-Component (or Unary) Phase Diagrams



Two-Components (or Binary) Phase Diagrams



Liquidus line separates liquid from liquid + solid
Solidus line separates solid from liquid + solid



- Tie line – connects the phases in equilibrium with each other – also sometimes called an isotherm (temperature is constant).
- If the present phase is L + α :
- The composition of α phase (C_α)can be found at the intersection of tie line with solidus line.
- The composition of L phase (C_L)can be found at the intersection of tie line with liquidus line.

- The weight fraction for each phase can be calculated using the following equations:

$$W_L = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$

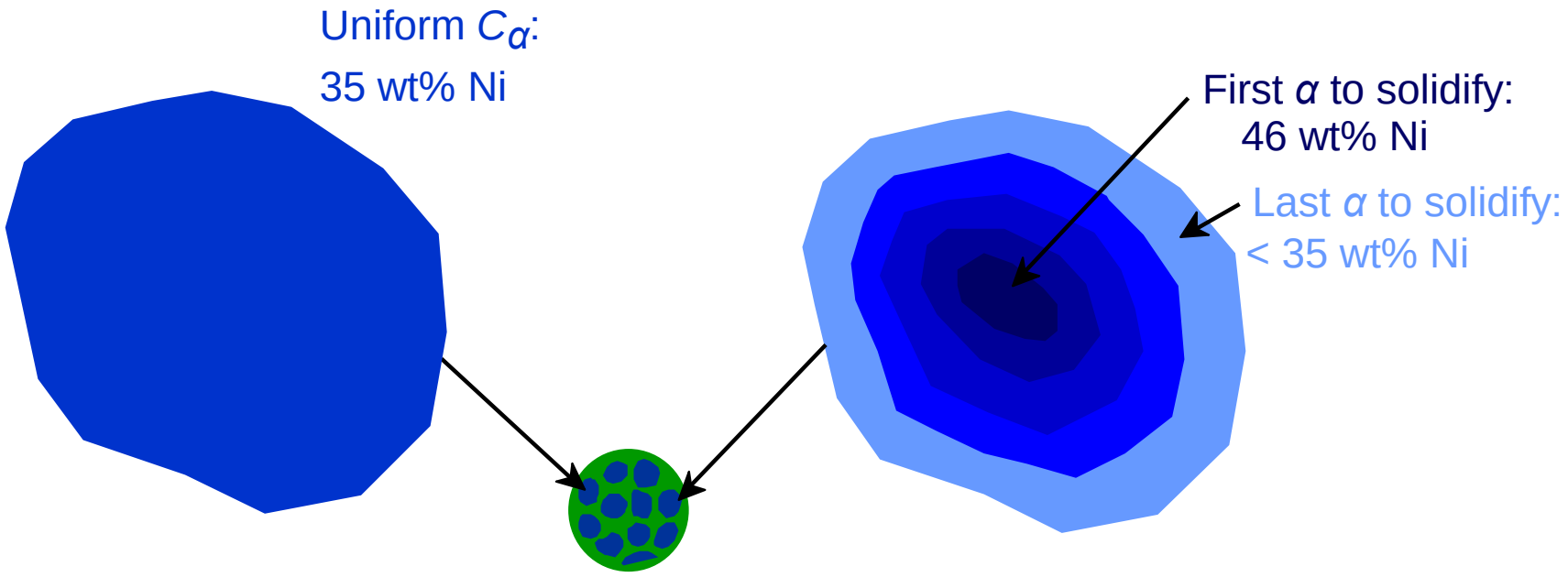
$$W_\alpha = \frac{C_0 - C_L}{C_\alpha - C_L}$$

Cored vs Equilibrium Structures

- C_α changes as we solidify.
- Cu-Ni case: First α to solidify has C_α = 46 wt% Ni.
  Last α to solidify has C_α = 35 wt% Ni.

- Slow rate of cooling:
  Equilibrium structure

- Fast rate of cooling:
  Cored structure



Binary-Eutectic Systems

2 components

has a special composition with a min. melting T.

Ex.: Cu-Ag system

- 3 single phase regions (L, α, β)
- Limited solubility:
  - α: mostly Cu
  - β: mostly Ag
- T_E: No liquid below T_E
- C_E: Composition at temperature T_E
- **Eutectic reaction**

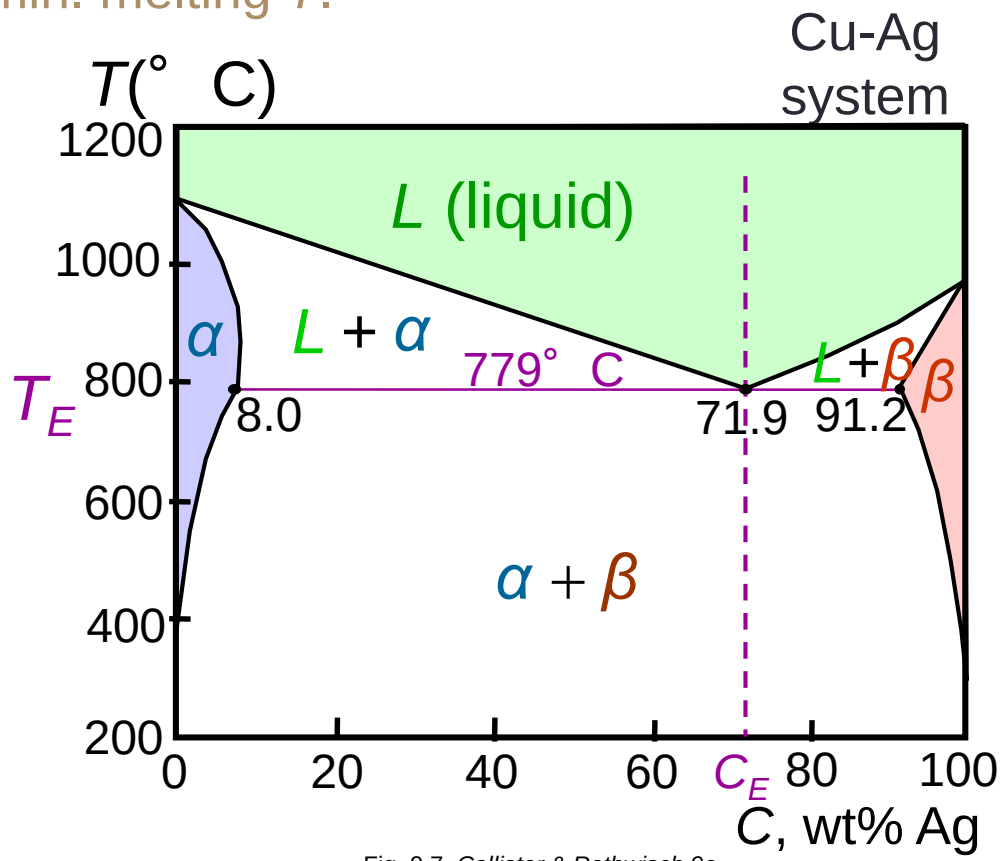
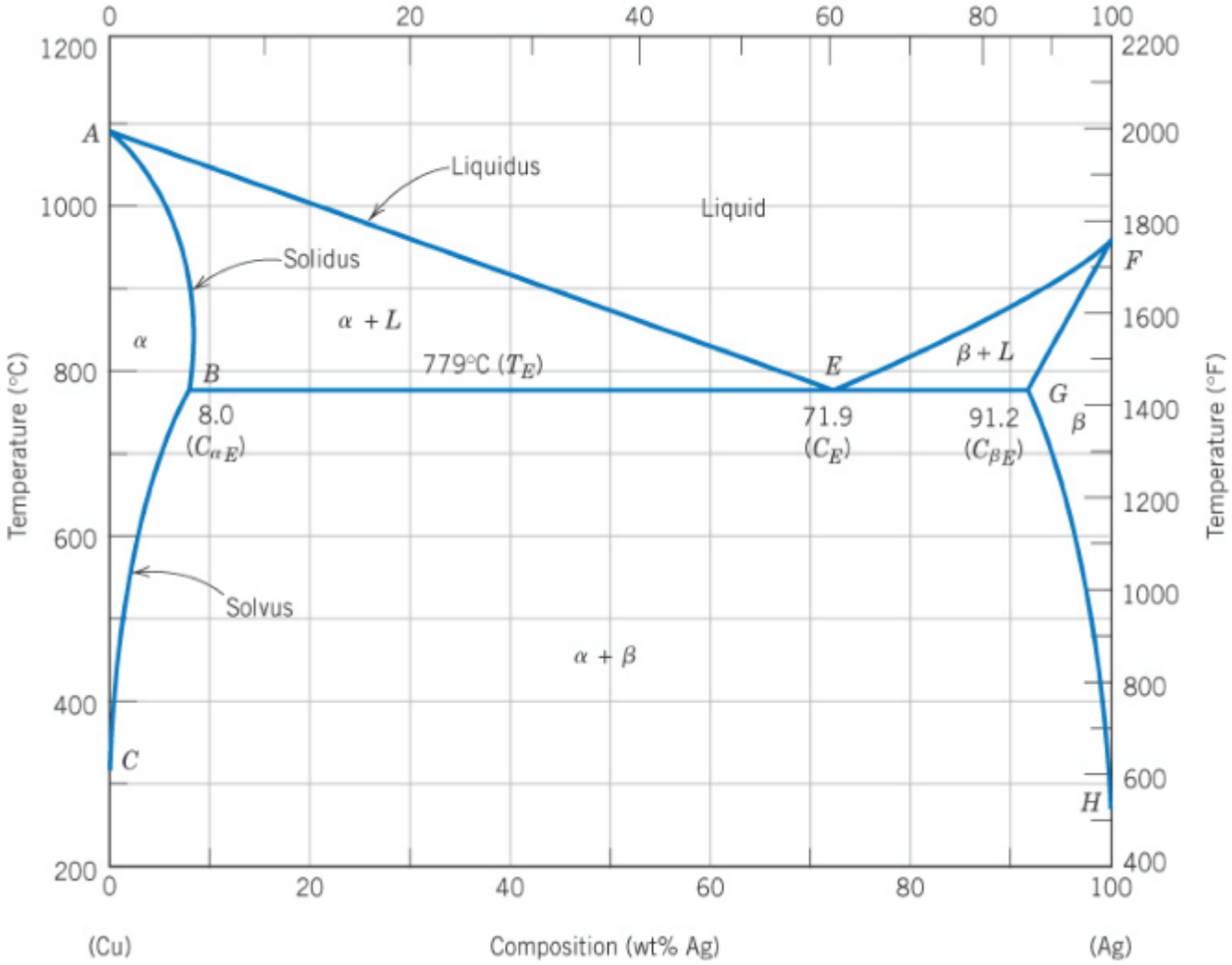


Fig. 9.7, *Callister & Rethwisch 9e*
[Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 1, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.].

$$L(C_E) \rightleftharpoons \alpha(C_{\alpha E}) + \beta(C_{\beta E})$$

$$L(71.9\text{ wt\% Ag}) \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \alpha(8.0\text{ wt\% Ag}) + \beta(91.2\text{ wt\% Ag})$$



Solvus line separates one solid solution from a mixture of solid solutions. **Solvus line shows limit of solubility**
Eutectic means easily melted

$$L(C_E) \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \alpha(C_{\alpha E}) + \beta(C_{\beta E})$$

$$L(71.9\ \text{wt\%}\ \text{Ag}) \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \alpha(8.0\ \text{wt\%}\ \text{Ag}) + \beta(91.2\ \text{wt\%}\ \text{Ag})$$

EX 1: Pb-Sn Eutectic System

- For a 40 wt% Sn-60 wt% Pb alloy at 150°C, determine:
  -- the phases present
  Answer:
  -- the phase compositions
  Answer:

  -- the relative amount of each phase
  Answer:

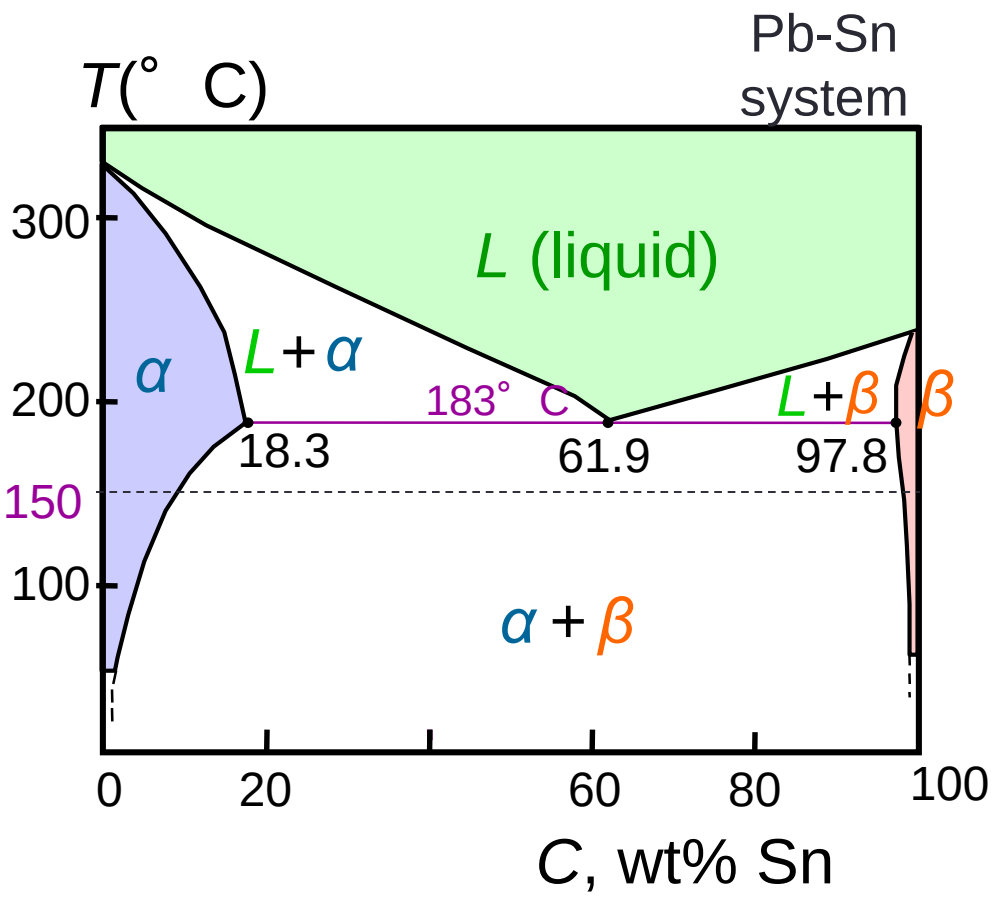


Fig. 9.8, *Callister & Rethwisch 9e.*
[Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 3, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

EX 2: Pb-Sn Eutectic System

- For a 40 wt% Sn-60 wt% Pb alloy at 220° C, determine:
  -- the phases present:
  Answer:
  -- the phase compositions
  Answer:
  -- the relative amount of each phase
  Answer:

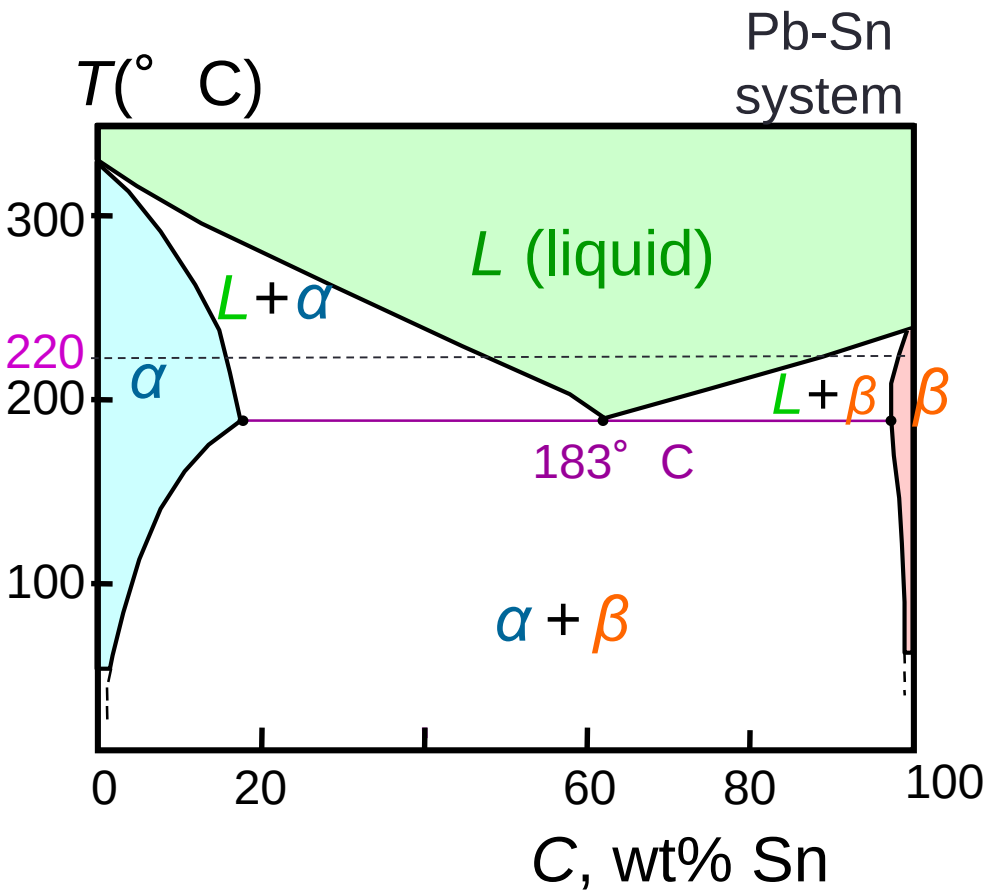


Fig. 9.8, *Callister & Rethwisch 9e.*
[Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 3, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Microstructural Developments in Eutectic Systems I

- For alloys for which
  C_0 < 2 wt% Sn
- Result: at room temperature
  -- polycrystalline with grains of
  α phase having
  composition C_0

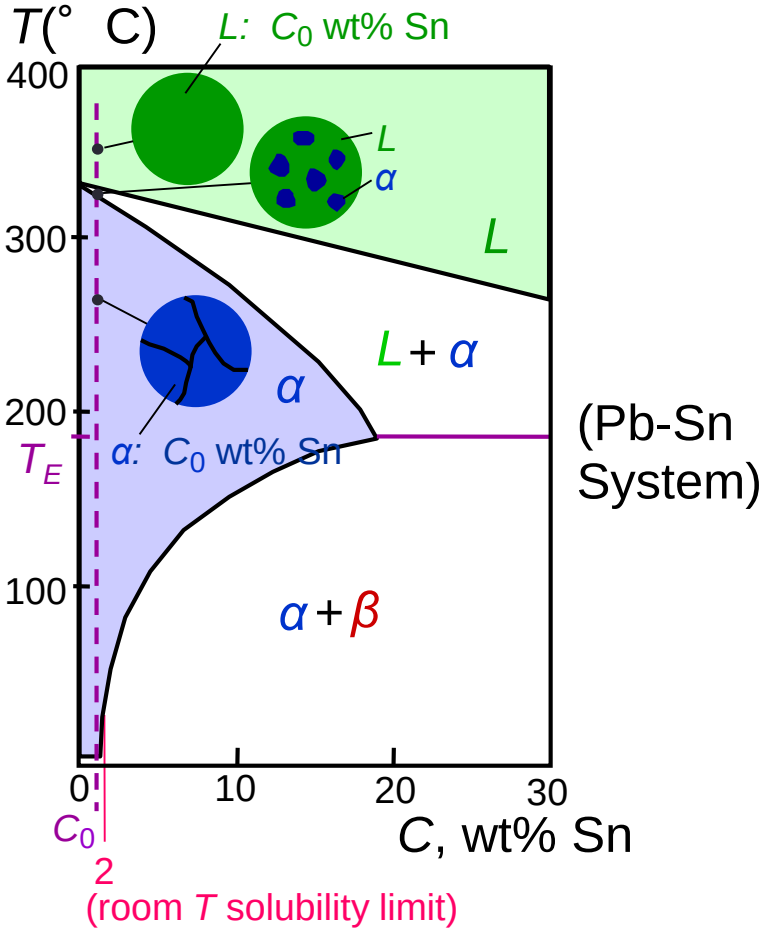


Fig. 9.11, *Callister & Rethwisch 9e.*

Microstructural Developments in Eutectic Systems II

- For alloys for which
  2 wt% Sn < C_0 < 18.3 wt% Sn
- Result:
  at temperatures in $\alpha + \beta$ range
  -- polycrystalline with α grains
  and small β-phase particles

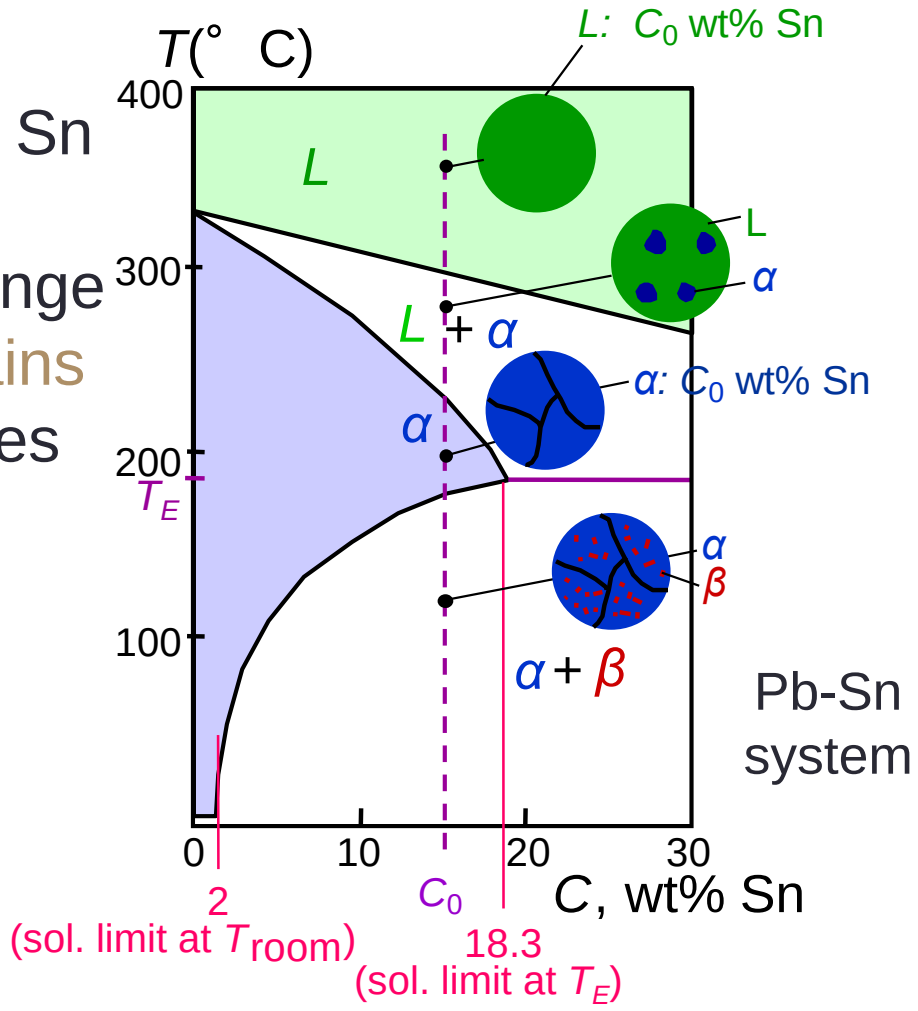


Fig. 9.12, *Callister & Rethwisch 9e.*

Microstructural Developments in Eutectic Systems III

- For alloy of composition $C_0 = C_E$
- Result: Eutectic microstructure (lamellar structure)
  -- alternating layers (lamellae) of α and β phases.

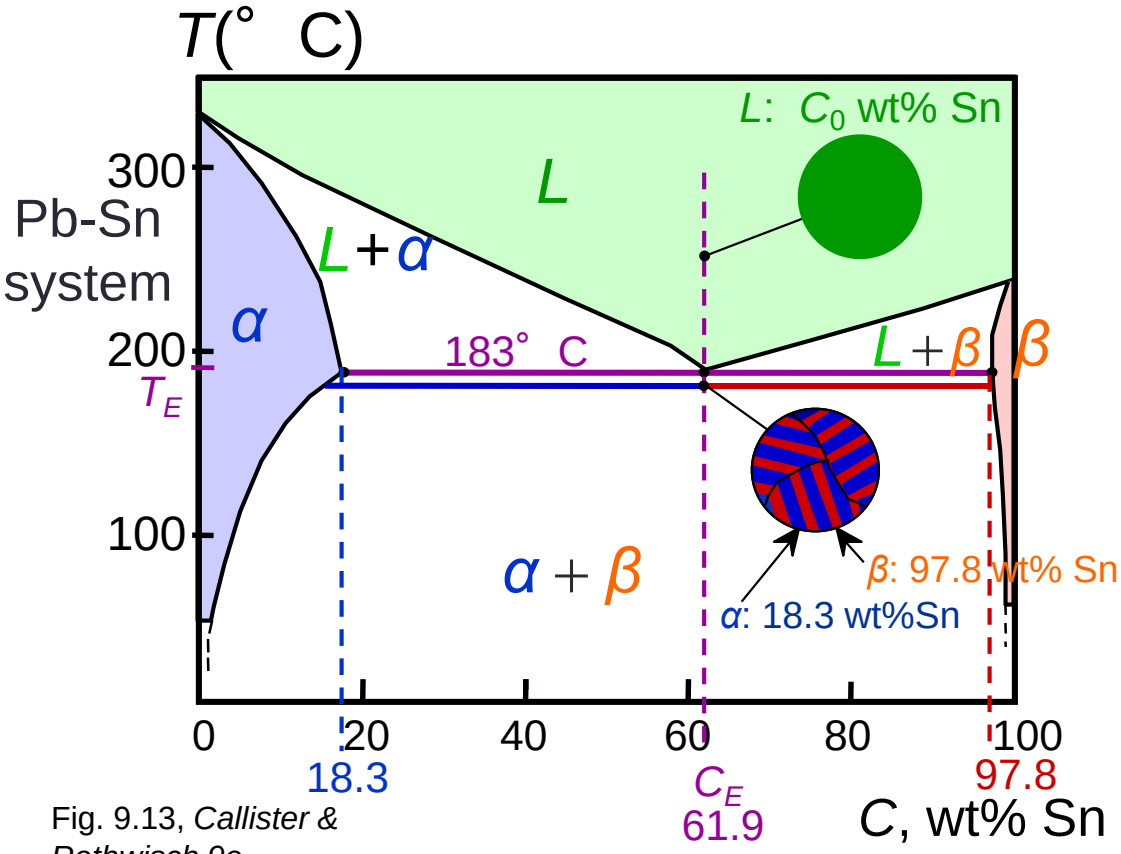


Fig. 9.13, *Callister & Rethwisch 9e.*

Micrograph of Pb-Sn eutectic microstructure

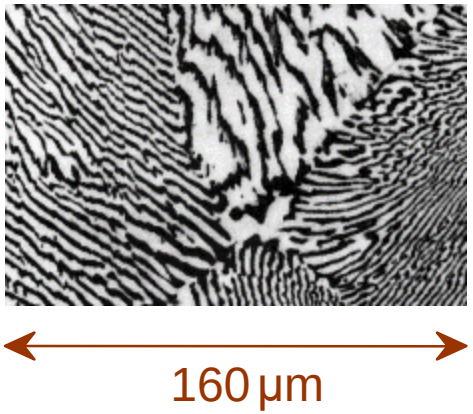
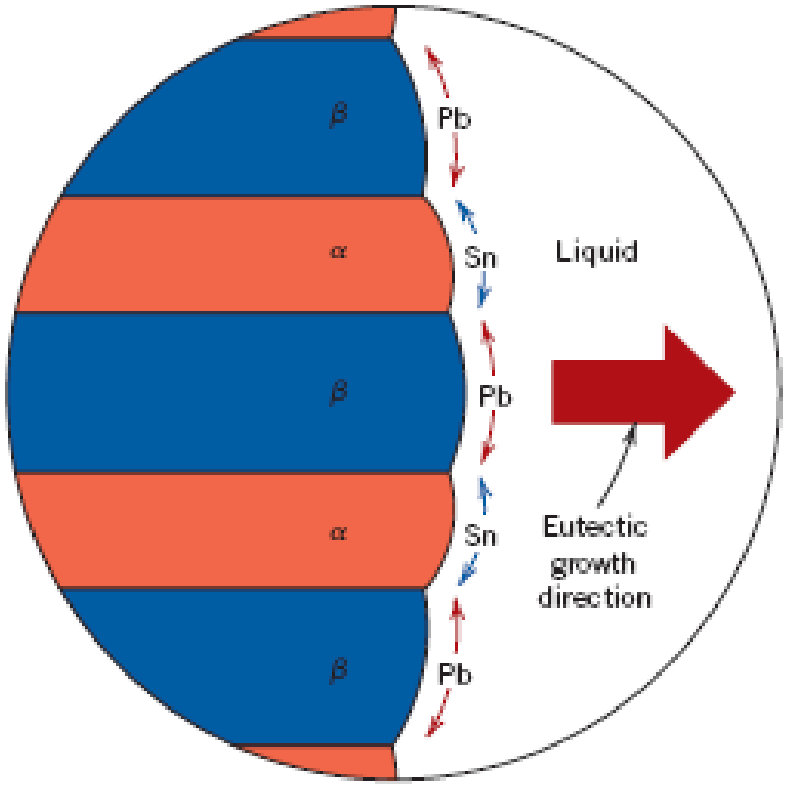
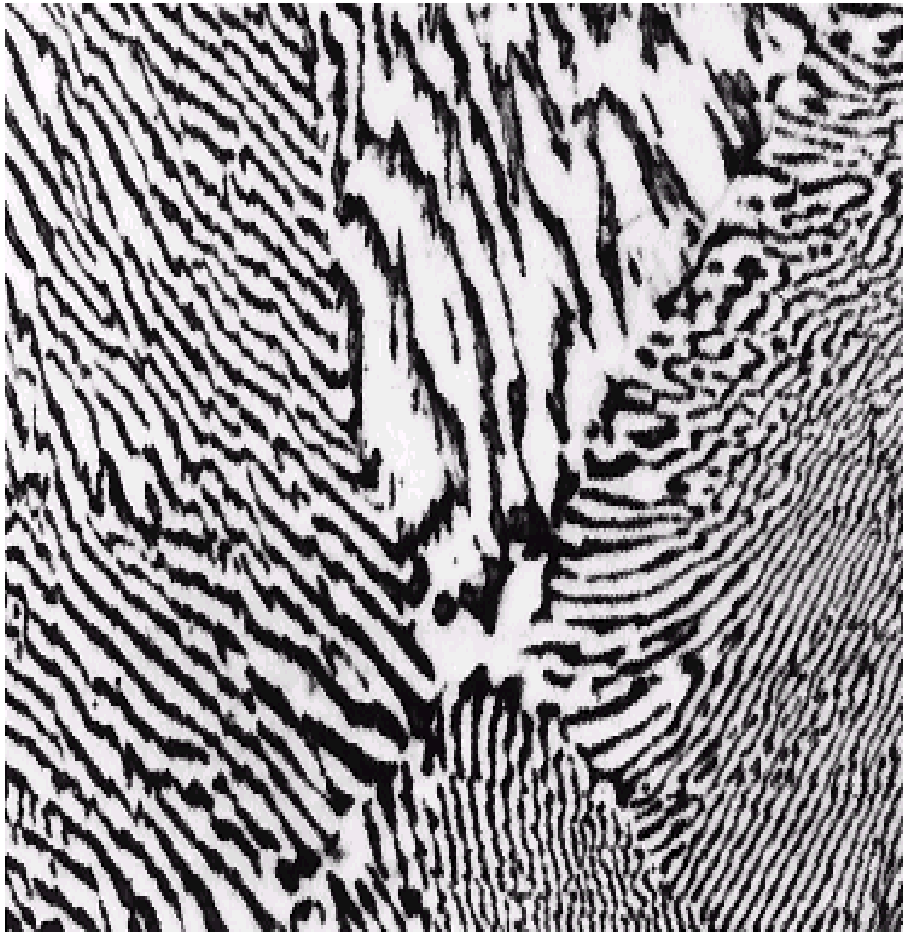


Fig. 9.14, *Callister & Rethwisch 9e.*
(From *Metals Handbook*, 9th edition, Vol. 9, *Metallography and Microstructures*, 1985. Reproduced by permission of ASM International, Materials Park, OH.)

Lamellar Eutectic Structure





Figs. 9.14 & 9.15, *Callister & Rethwisch 9e.*
(Fig. 9.14 from *Metals Handbook*, 9th edition, Vol. 9, *Metallography and Microstructures*, 1985. Reproduced by permission of ASM International, Materials Park, OH.)

Microstructural Developments in Eutectic Systems IV

- For alloys for which 18.3 wt% Sn < C_0 < 61.9 wt% Sn
- Result: α phase particles and a eutectic microconstituent

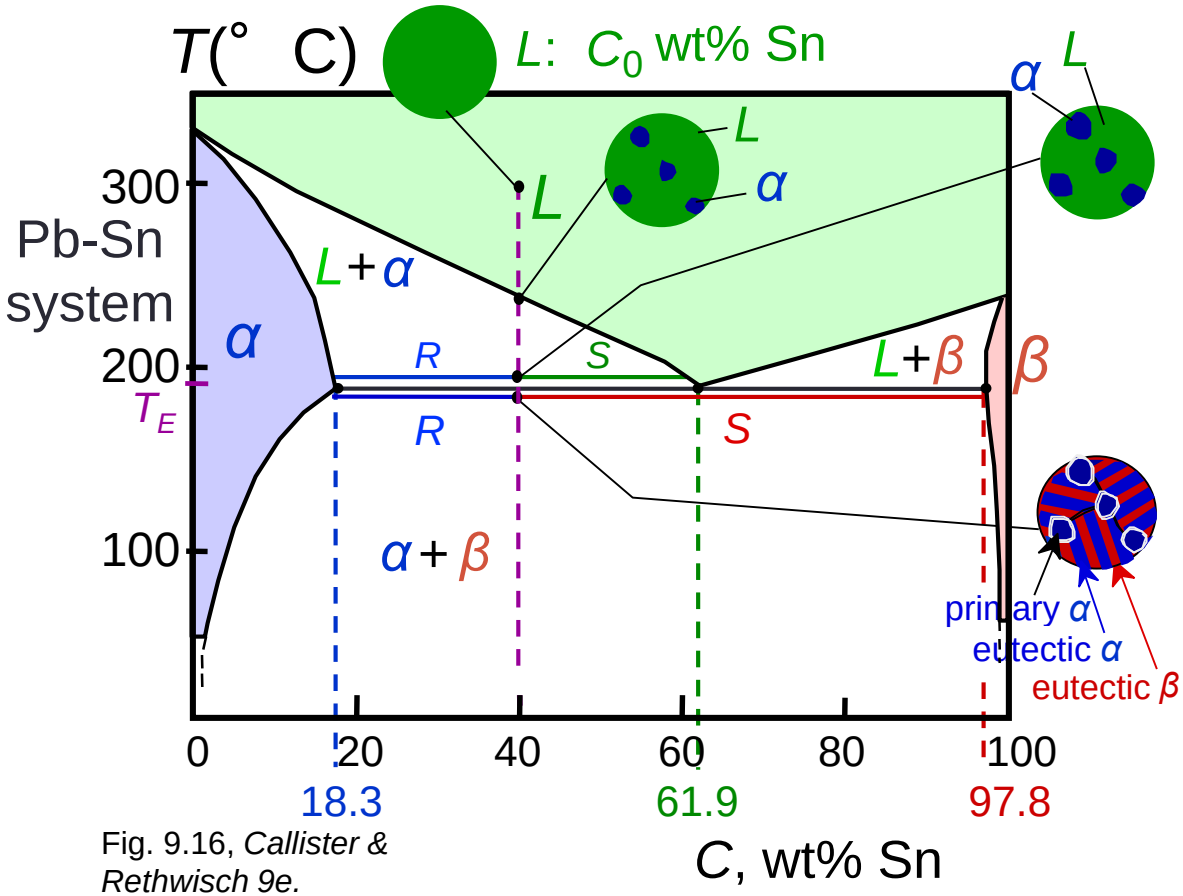


Fig. 9.16, *Callister & Rethwisch 9e.*

- Just above T_E :

C_α = 18.3 wt% Sn

C_L = 61.9 wt% Sn

$W_\alpha = \frac{61.9-40}{61.9-18.3} = 0.50$

$W_L = (1-W\alpha) = 0.50$

- Just below T_E :

$C\alpha$ = 18.3 wt% Sn

C_β = 97.8 wt% Sn

$W_\alpha = \frac{97.8-40}{97.8-18.3} = 0.73$

$W_\beta = 0.27$

Hypoeutectic & Hypereutectic

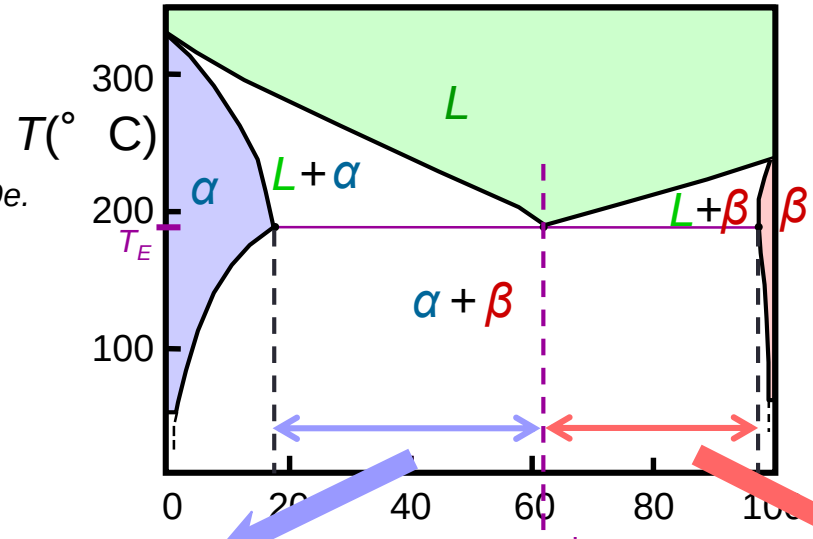
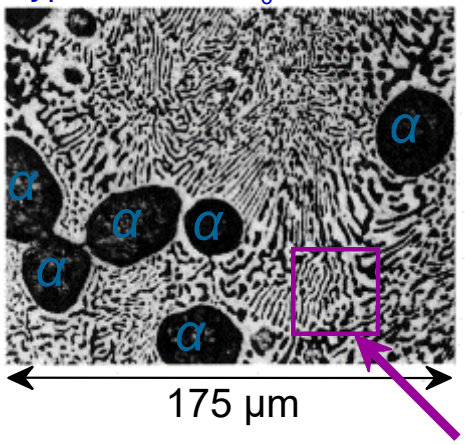
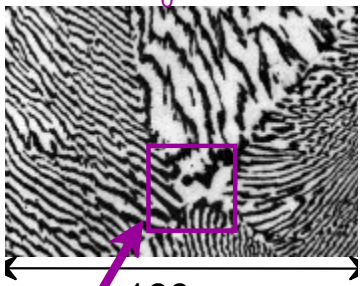


Fig. 9.8, *Callister & Rethwisch 9e.* [Adapted from *Binary Alloy Phase Diagrams*, 2nd edition, Vol. 3, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

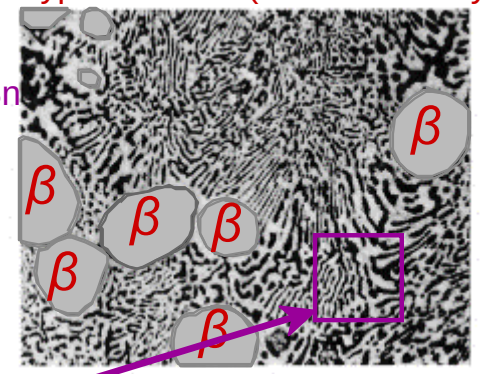
hypoeutectic: C_0 = 50 wt% Sn



eutectic: C_0 = 61.9 wt% Sn



hypereutectic: (illustration only)



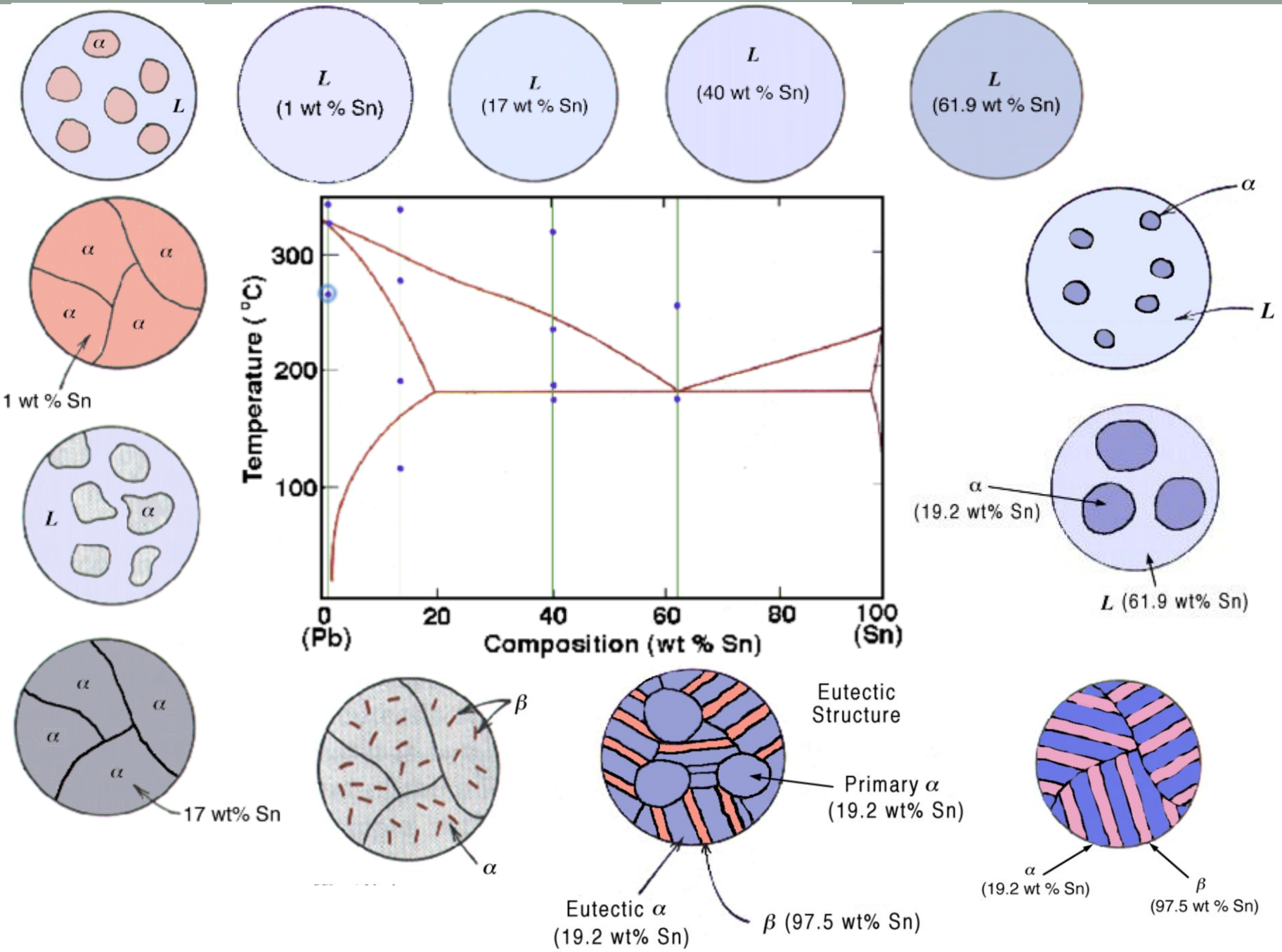
(Figs. 9.14 and 9.17 from *Metals Handbook*, 9th ed., Vol. 9, *Metallography and Microstructures*, 1985. Reproduced by permission of ASM International, Materials Park, OH.)

Fig. 9.17, *Callister & Rethwisch 9e.*

eutectic micro-constituent

Fig. 9.14, *Callister & Rethwisch 9e.*

Adapted from Fig. 9.17, *Callister & Rethwisch 9e.* (Illustration only)


α
L
L
(1 wt % Sn)
L
(17 wt % Sn)
L
(40 wt % Sn)
L
(61.9 wt % Sn)
α
α
α
α
1 wt % Sn
α
L
Temperature (°C)
300
200
100
0
(Pb)
20
40
60
80
100
(Sn)
Composition (wt % Sn)
α
L
α
(19.2 wt% Sn)
L (61.9 wt% Sn)
α
α
α
α
17 wt% Sn
β
α
Eutectic
Structure
Primary α
(19.2 wt% Sn)
Eutectic α
(19.2 wt% Sn)
β (97.5 wt% Sn)
α
(19.2 wt % Sn)
β
(97.5 wt % Sn)

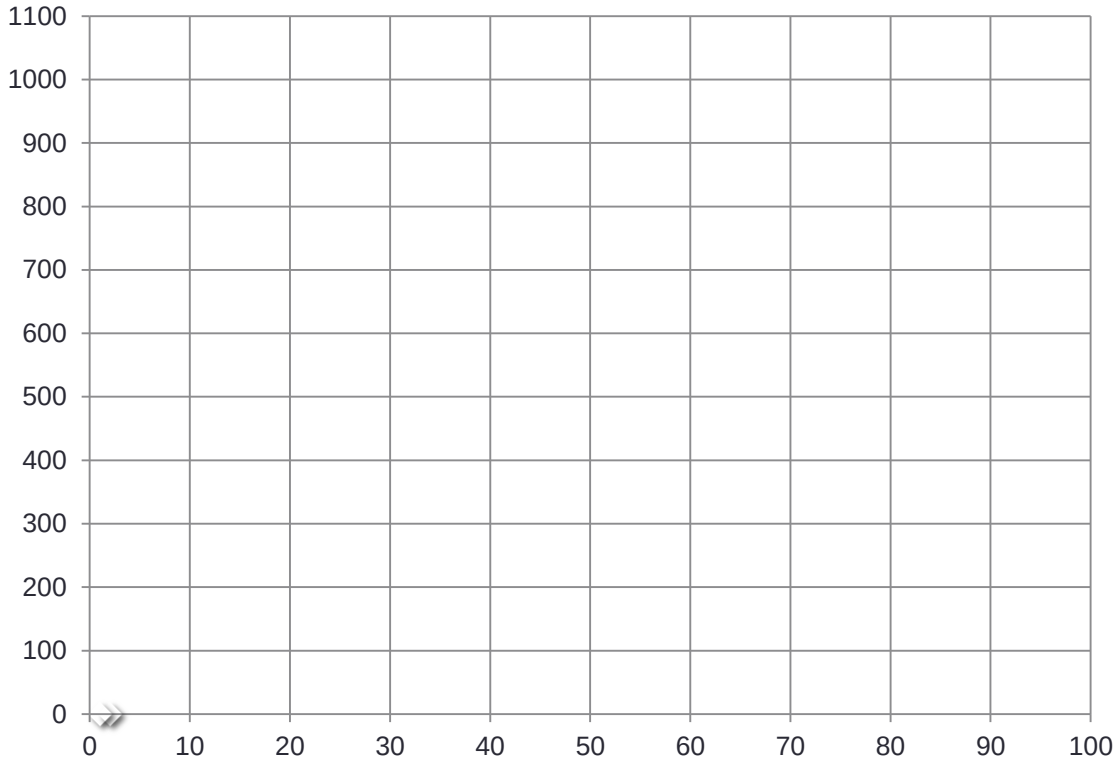
Given the following information for hypothetical (A-B) binary system, which is totally soluble in liquid state and partially soluble in solid state with eutectic reaction.

- Melting temperature of elements A and B are 1000°C and 800 °C;
- Eutectic temperature and composition are 550 °C and 50 %B, Maximum solubility of B in A (α-phase) is 10 % B at the eutectic temperature
- Maximum solubility of A in B (β-phase) is 15 % A at the eutectic temperature

Consider that the solubility of α and β phases are diminished at room temperature and all phase boundaries are straight lines.

It is required to:

1) Sketch to scale the phase diagram.
2) 2) On your sketch write the different phases and information.
3) For the 30%B alloy composition, determine the phases just existed at the end of solidification and calculate the total amounts of α-phase in this alloy.



Q. Cite the phases that are present, the phase compositions and the relative amounts (in terms of mass fractions) for the following alloys:

(a) 75 wt% Sn-25 wt% Pb at 175°C (345°F)

(b) 55 wt% Ag-45 wt% Cu at 900°C (1650°F)

(c) 8.2 mol Ni and 4.3 mol Cu at 1250°C (2280°F)

(d) 4.5 mol Sn and 0.45 mol Pb at 200°C (390°F)

The atomic weights for Ni, Cu, Sn and Pb are 58.69, 63.55, 118.71 and 207.2 g/mol respectively.

Q. *A 1.5-kg specimen of a 90 wt% Pb–10 wt% Sn alloy is heated to 250°C (480°F); at this temperature it is entirely an a-phase solid solution (Figure 9.8). The alloy is to be melted to the extent that 50% of the specimen is liquid, the remainder being the a phase. This may be accomplished either by heating the alloy or changing its composition while holding the temperature constant.*

(a) To what temperature must the specimen be heated?

(b) How much tin must be added to the 1.5-kg specimen at 250°C to achieve this state?

Q. Is it possible to have a copper-silver alloy in which the mass fractions of primary β and total β are 0.68 and 0.925, respectively, at 775°C (1425°F)? Why or why not?

Q. The microstructure of a lead-tin alloy at 180°C (355°F) consists of primary β and eutectic structures. If the mass fractions of these two microconstituents are 0.57 and 0.43, respectively, determine the composition of the alloy.

Q. For a copper-silver alloy of composition 25 wt% Ag-75 wt% Cu and at 775°C (1425°F) do the following:

(a) Determine the mass fractions of α and β phases.

(b) Determine the mass fractions of primary α and eutectic microconstituents.

(c) Determine the mass fraction of eutectic α.