

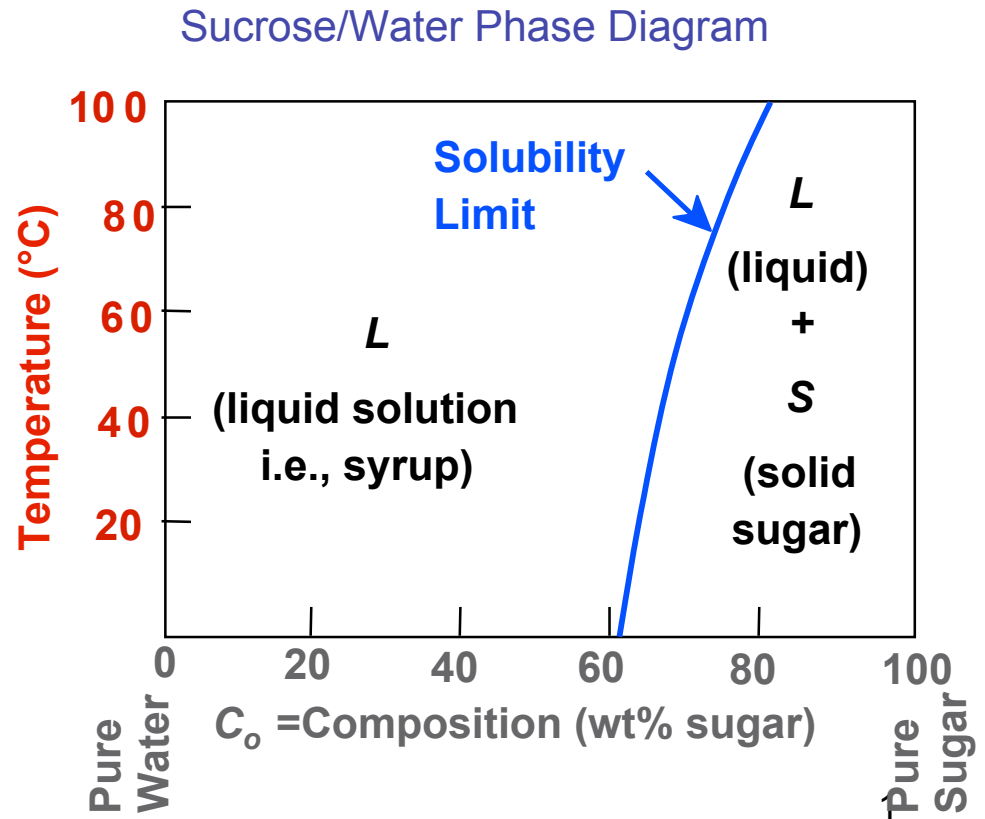
Phase equilibria: solubility limit

Introduction

- **Solutions** – solid solutions, single phase
- **Mixtures** – more than one phase

Adapted from Fig. 9.1,
Callister 7e.

- **Solubility Limit:**
Max concentration for
which only a single phase
solution occurs.

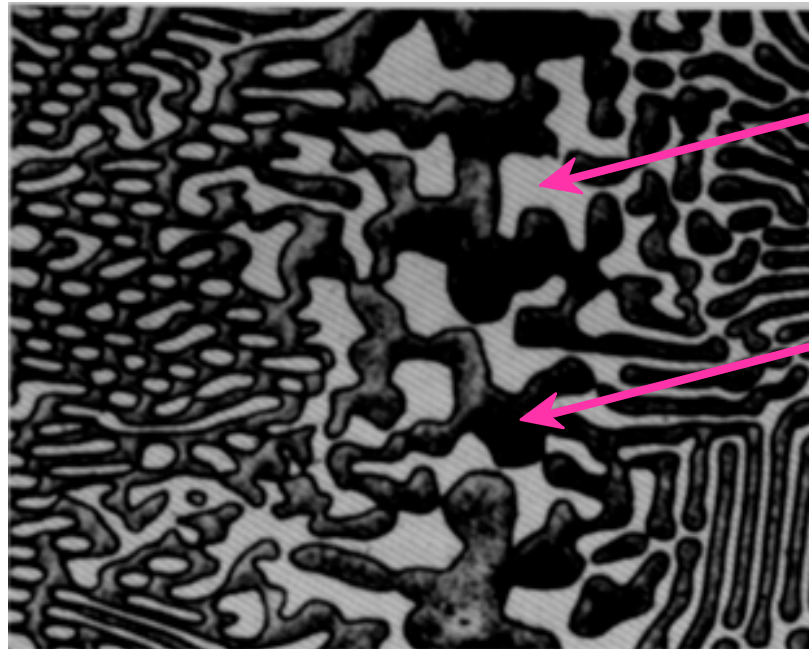


Components and phases

- **Components:**
The elements or compounds which are present in the mixture (e.g., Al and Cu)
- **Phases:**
The physically and chemically distinct material regions that result (e.g., α and β).

Aluminum-
Copper
Alloy

Adapted from
chapter-opening
photograph,
Chapter 9,
Callister 3e.



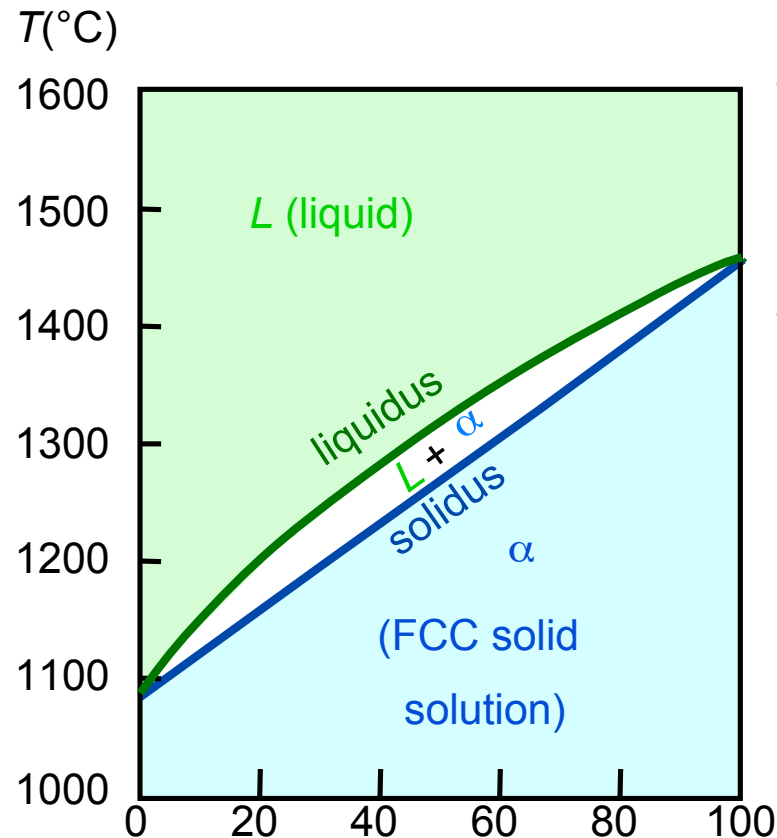
β (lighter
phase)

α (darker
phase)

Phase diagrams

- Indicate phases as function of T , C_o , and P .
- For this course:
 - binary systems: just 2 components.
 - independent variables: T and C_o ($P = 1$ atm is almost always used).

- Phase Diagram for Cu-Ni system



- 2 phases:

L (liquid)

α (FCC solid solution)

- 3 phase fields:

L

$L + \alpha$

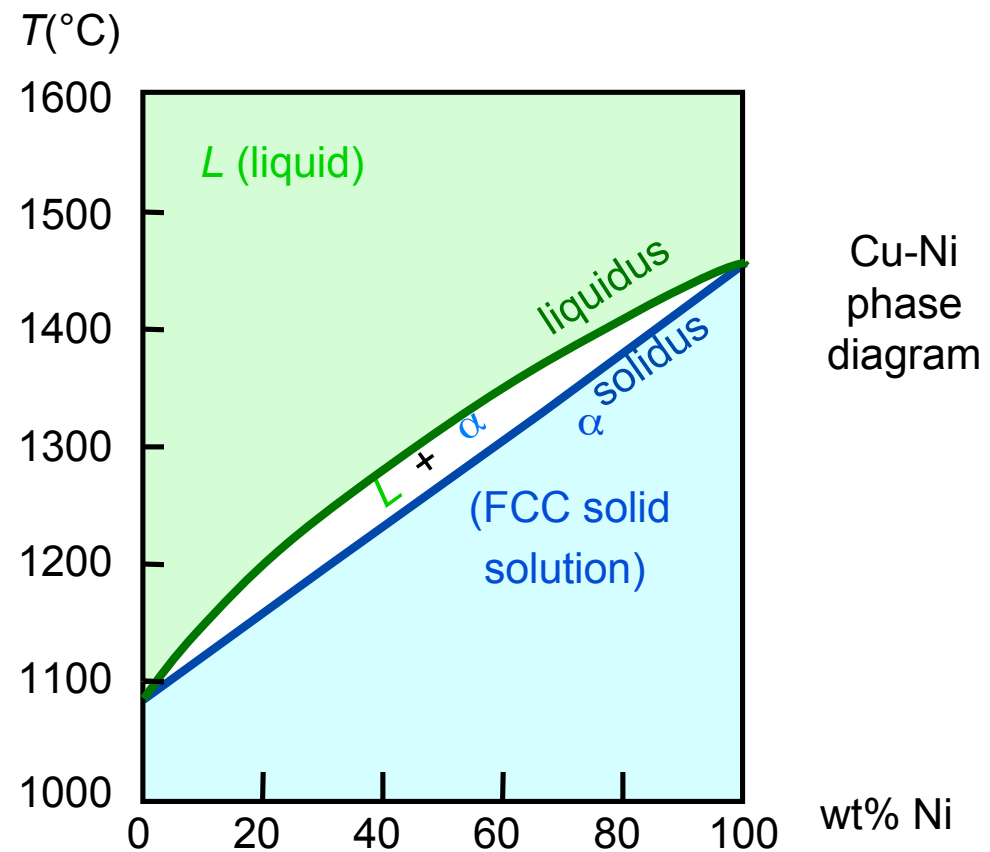
α

Adapted from Fig. 9.3(a), *Callister 7e*.
(Fig. 9.3(a) is adapted from *Phase Diagrams of Binary Nickel Alloys*, P. Nash (Ed.), ASM International, Materials Park, OH (1991).

Phase diagrams

- Rule 1: If we know T and C_o , then we know:
--the # and types of phases present.

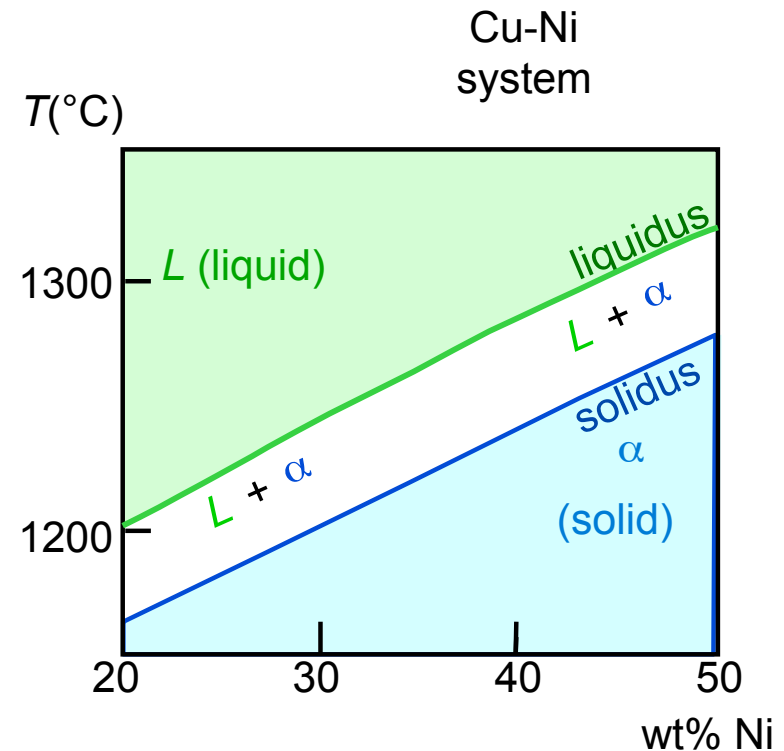
- Examples:



Adapted from Fig. 9.3(a), *Callister 7e*.
(Fig. 9.3(a) is adapted from *Phase Diagrams of Binary Nickel Alloys*, P. Nash (Ed.), ASM International, Materials Park, OH, 1991).

Phase diagrams

- Rule 2: If we know T and C_o , then we know:
 - the composition of each phase.
- Examples:



Adapted from Fig. 9.3(b), *Callister 7e*.
(Fig. 9.3(b) is adapted from *Phase Diagrams of Binary Nickel Alloys*, P. Nash (Ed.), ASM International, Materials Park, OH, 1991.)

Phase diagrams

- Rule 3: If we know T and C_o , then we know:
--the amount of each phase (given in wt%).

- Examples:

$C_o = 35 \text{ wt\% Ni}$

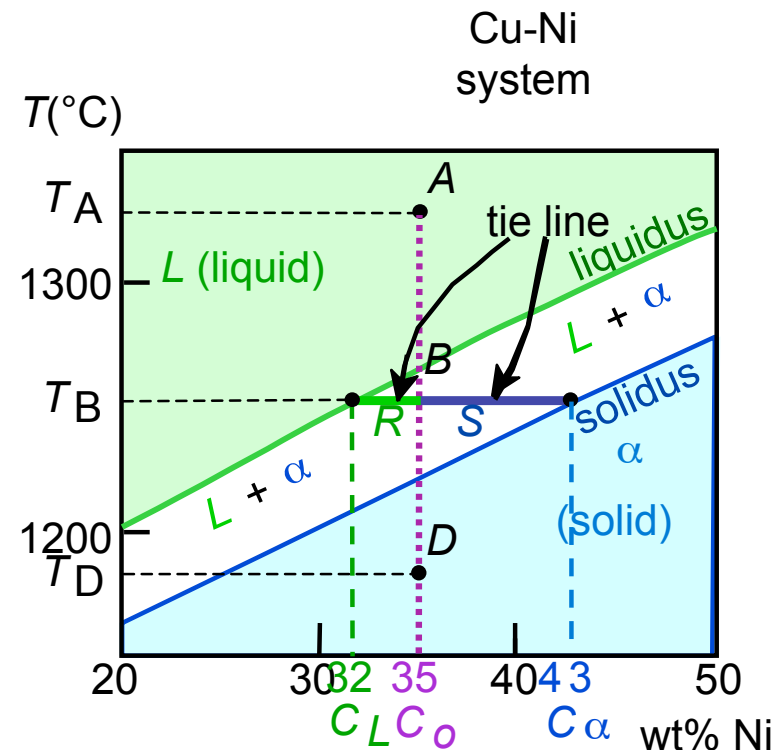
At T_A : Only Liquid (L)

$W_L = 100 \text{ wt\%}, W_\alpha = 0$

At T_D : Only Solid (α)

$W_L = 0, W_\alpha = 100 \text{ wt\%}$

At T_B : Both α and L

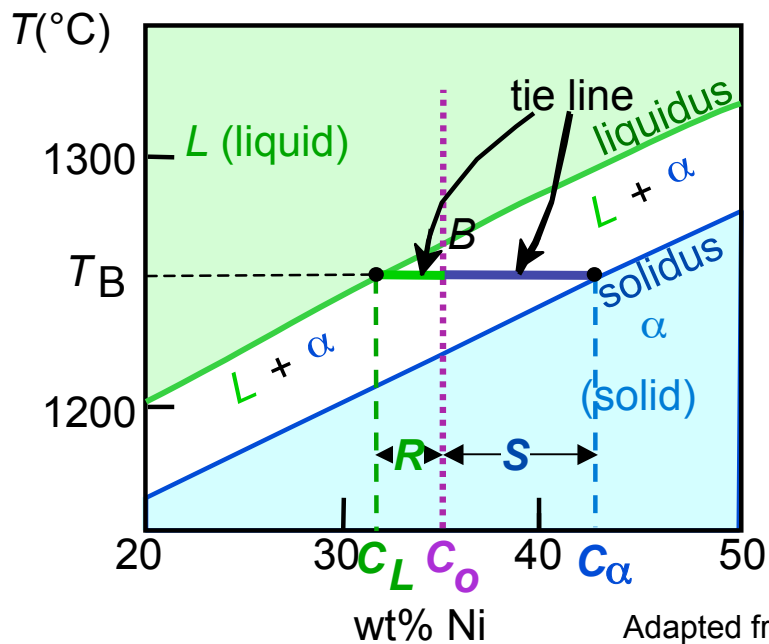


Adapted from Fig. 9.3(b), Callister 7e.

(Fig. 9.3(b) is adapted from *Phase Diagrams of Binary Nickel Alloys*, P. Nash (Ed.), ASM International, Materials Park, OH, 1991.)

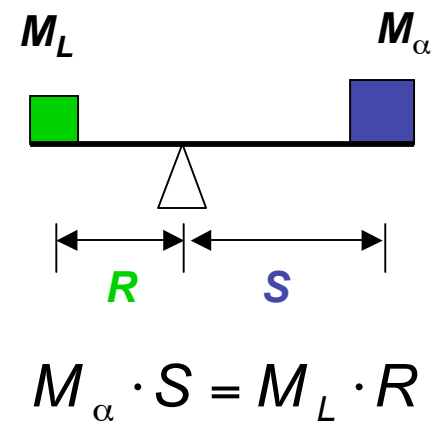
The lever rule

Tie line – connects the phases in equilibrium with each other - essentially an isotherm



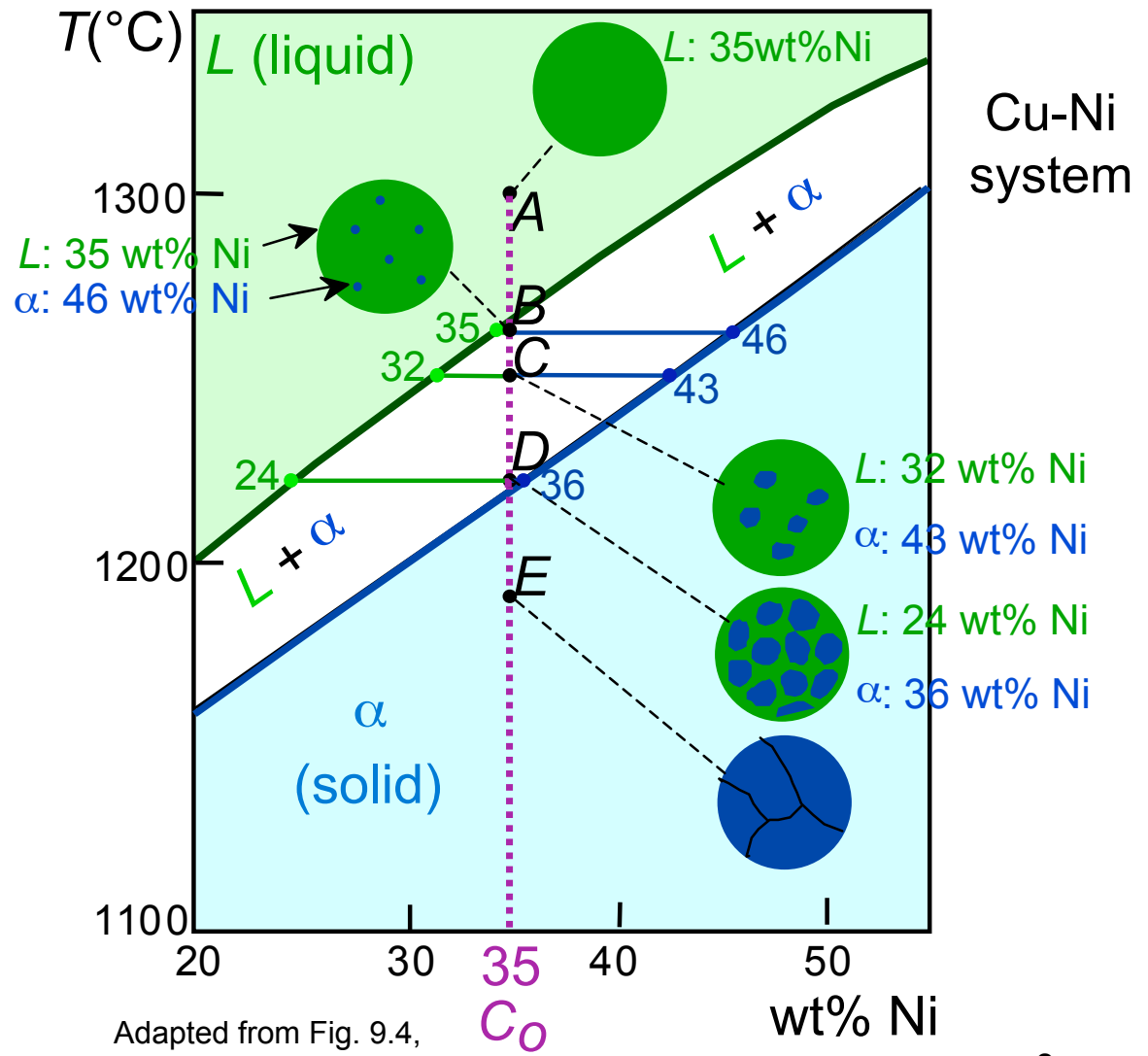
Adapted from Fig. 9.3(b),
Callister 7e.

How much of each phase?
Think of it as a lever (teeter-totter)



Cooling

- Phase diagram:
Cu-Ni system.
- System is:
 - binary
i.e., 2 components:
Cu and Ni.
 - isomorphous
i.e., complete
solubility of one
component in
another; α phase
field extends from
0 to 100 wt% Ni.
- Consider
 $C_o = 35 \text{ wt\% Ni}$.



Binary eutectic systems

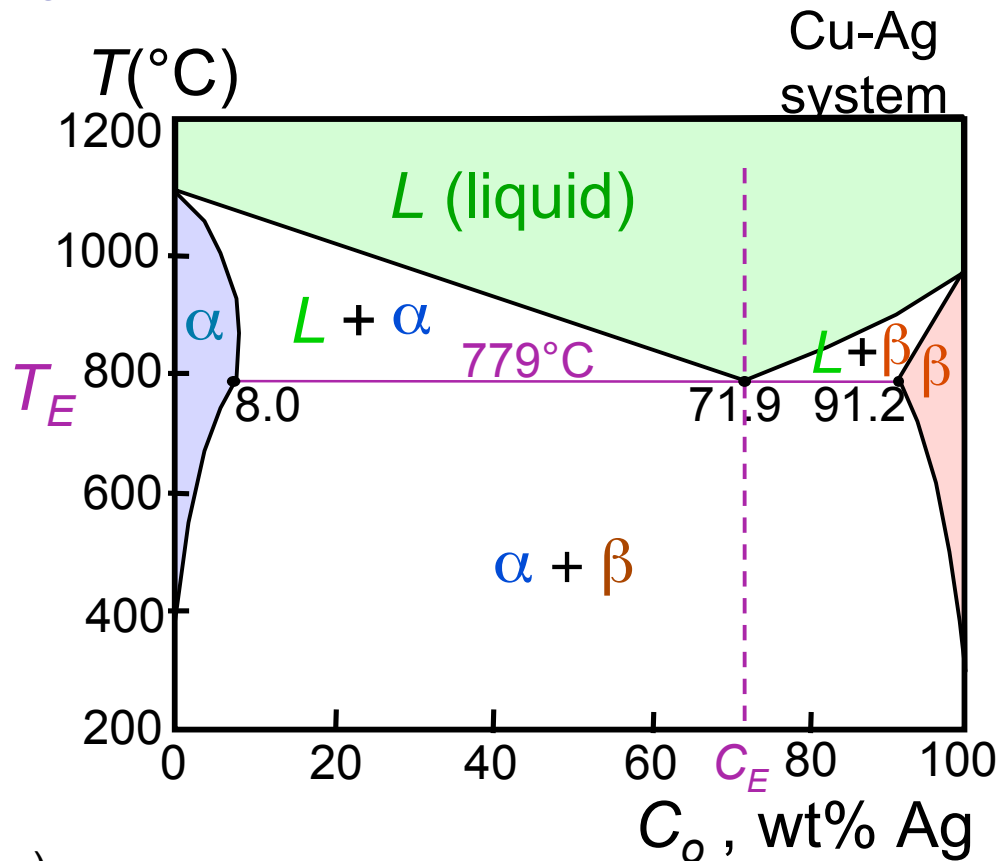
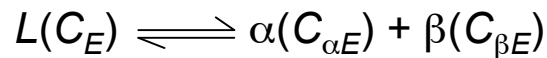
2 components

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 : Min. melting T_E composition

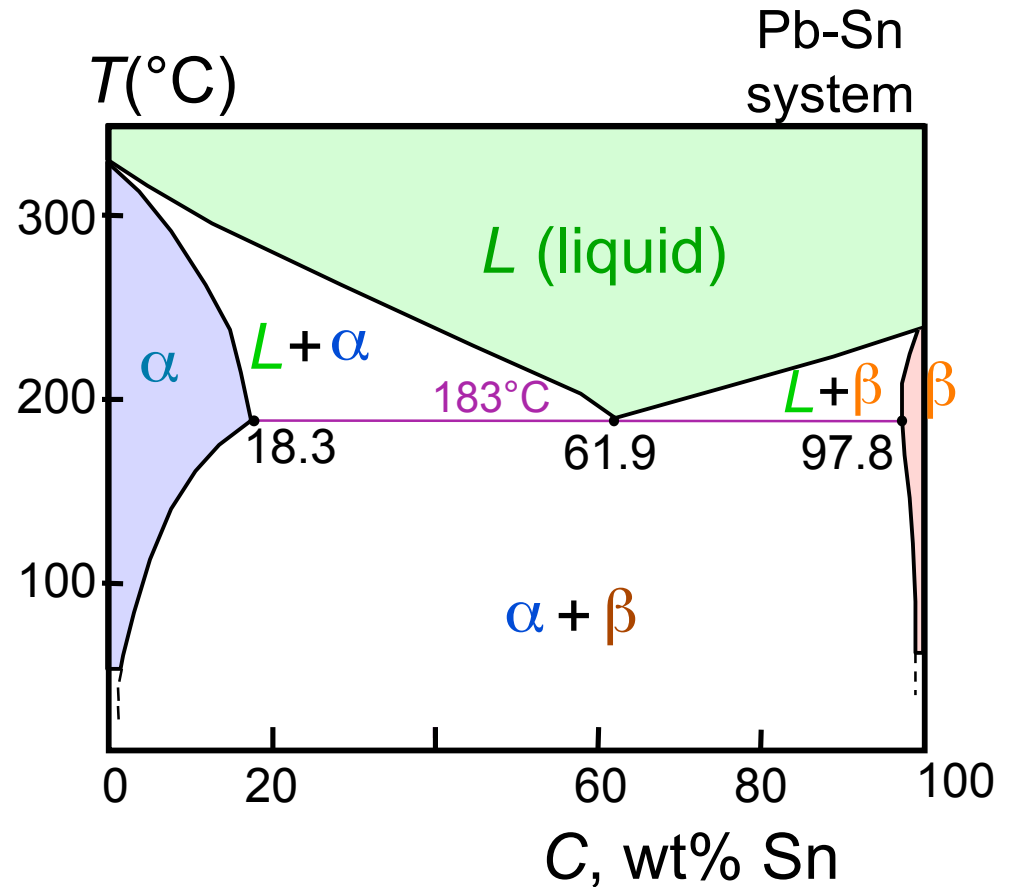
Eutectic transition



Adapted from Fig. 9.7,
Callister 7e.

Binary eutectic systems

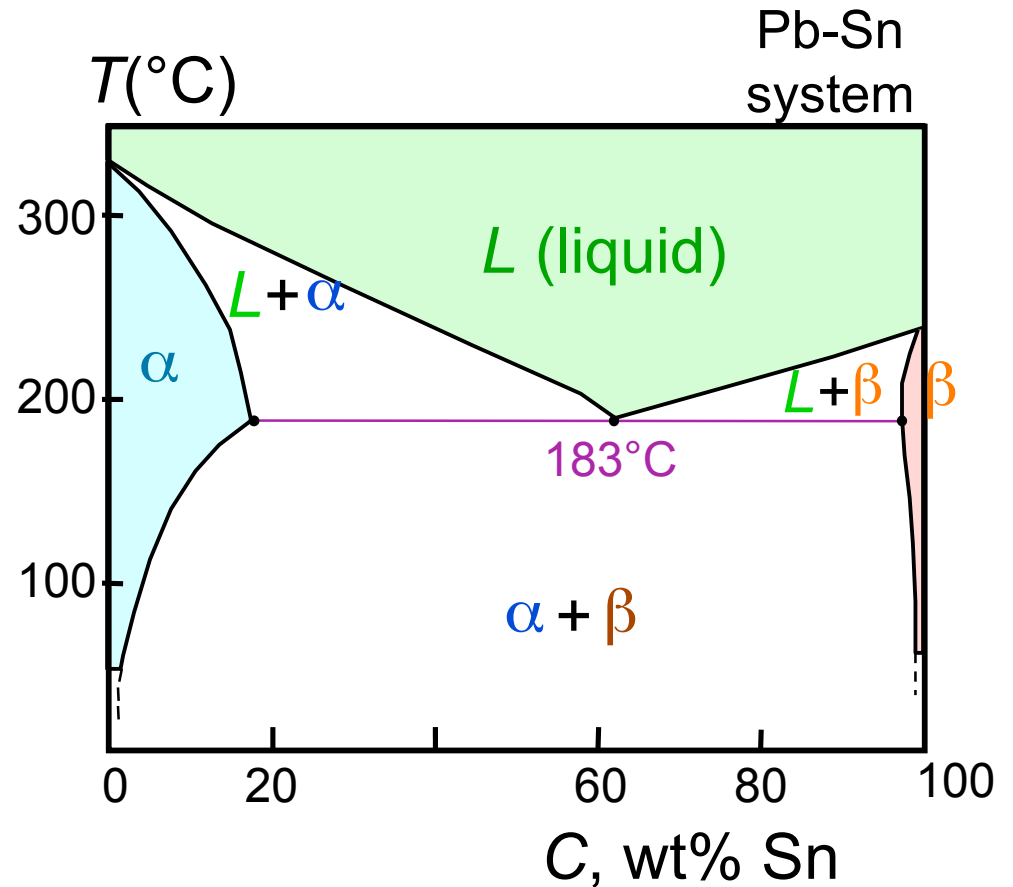
- For a 40 wt% Sn-60 wt% Pb alloy at 150°C, find...
--the phases present:



Adapted from Fig. 9.8,
Callister 7e.

Binary eutectic systems

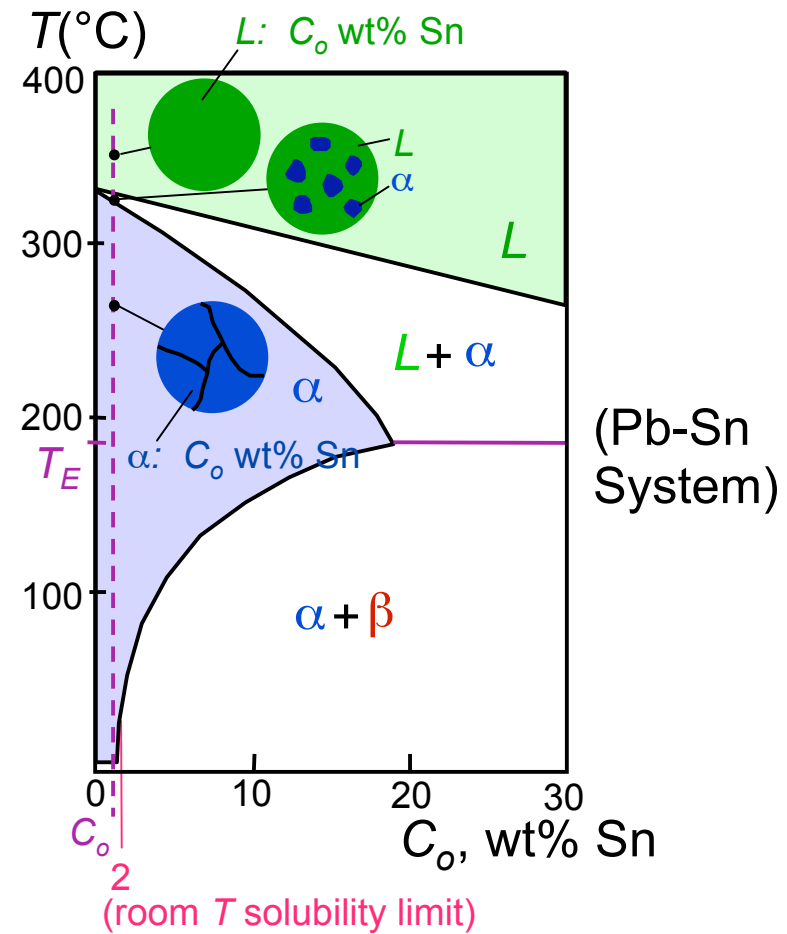
- For a 40 wt% Sn-60 wt% Pb alloy at 200°C, find...
--the phases present:



Adapted from Fig. 9.8,
Callister 7e.

Microstructures in eutectic systems

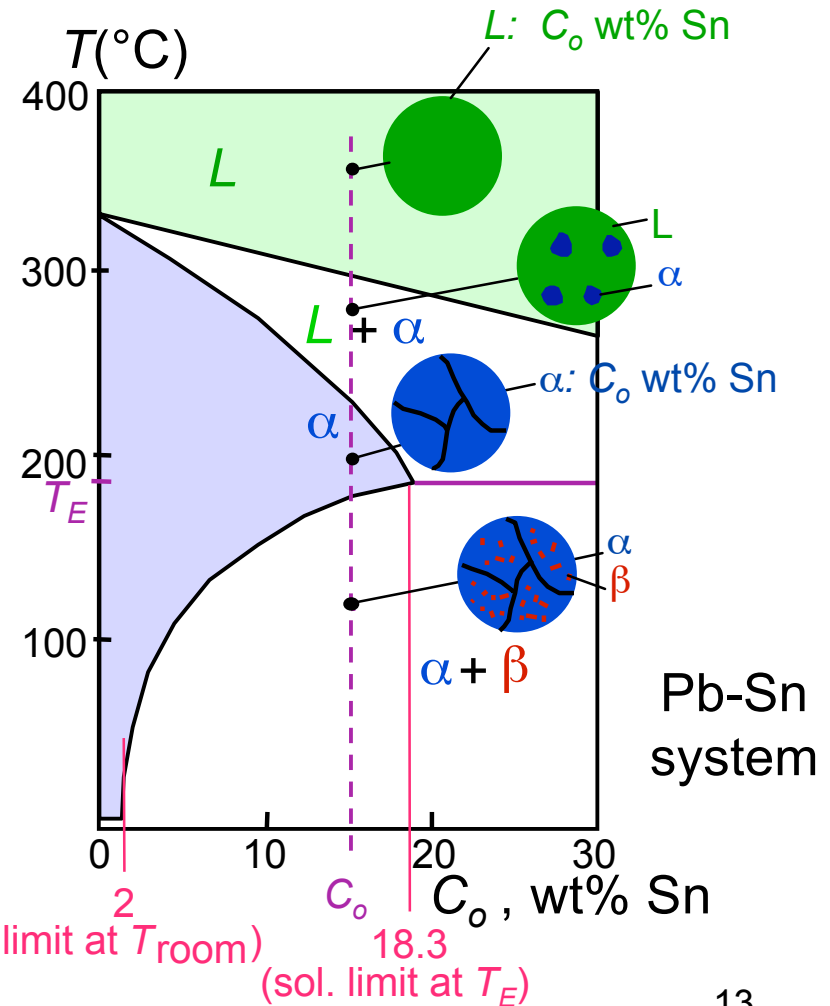
- $C_o < 2 \text{ wt\% Sn}$
- Result:
 - at extreme ends
 - polycrystal of α grains
i.e., only one solid phase.



Adapted from Fig. 9.11,
Callister 7e.

Microstructures in eutectic systems

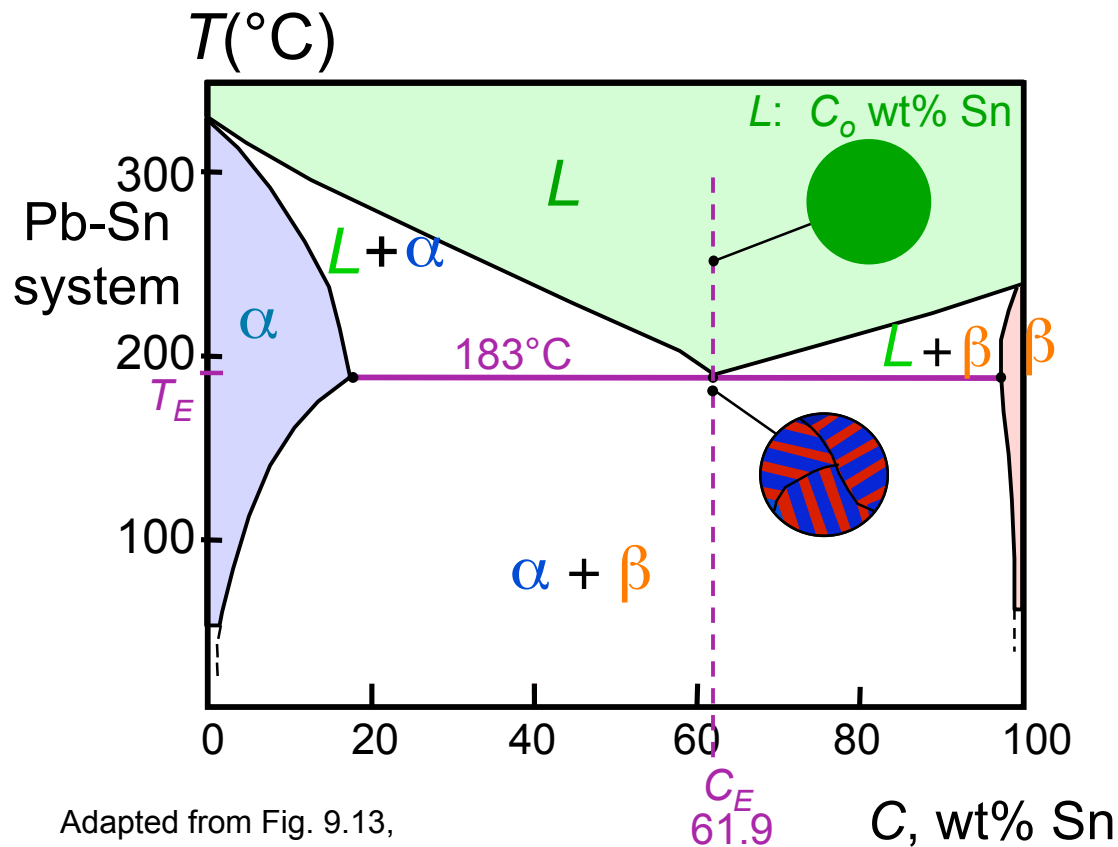
- 2 wt% Sn < C_o < 18.3 wt% Sn
- Result:
 - Initially liquid + α
 - then α alone
 - finally two phases
 - α polycrystal
 - fine β -phase inclusions



Adapted from Fig. 9.12,
Callister 7e.

Microstructures in eutectic systems

- $C_o = C_E$
- Result: Eutectic microstructure (lamellar structure)
--alternating layers (lamellae) of α and β crystals.



Adapted from Fig. 9.13,
Callister 7e.

Micrograph of Pb-Sn
eutectic
microstructure

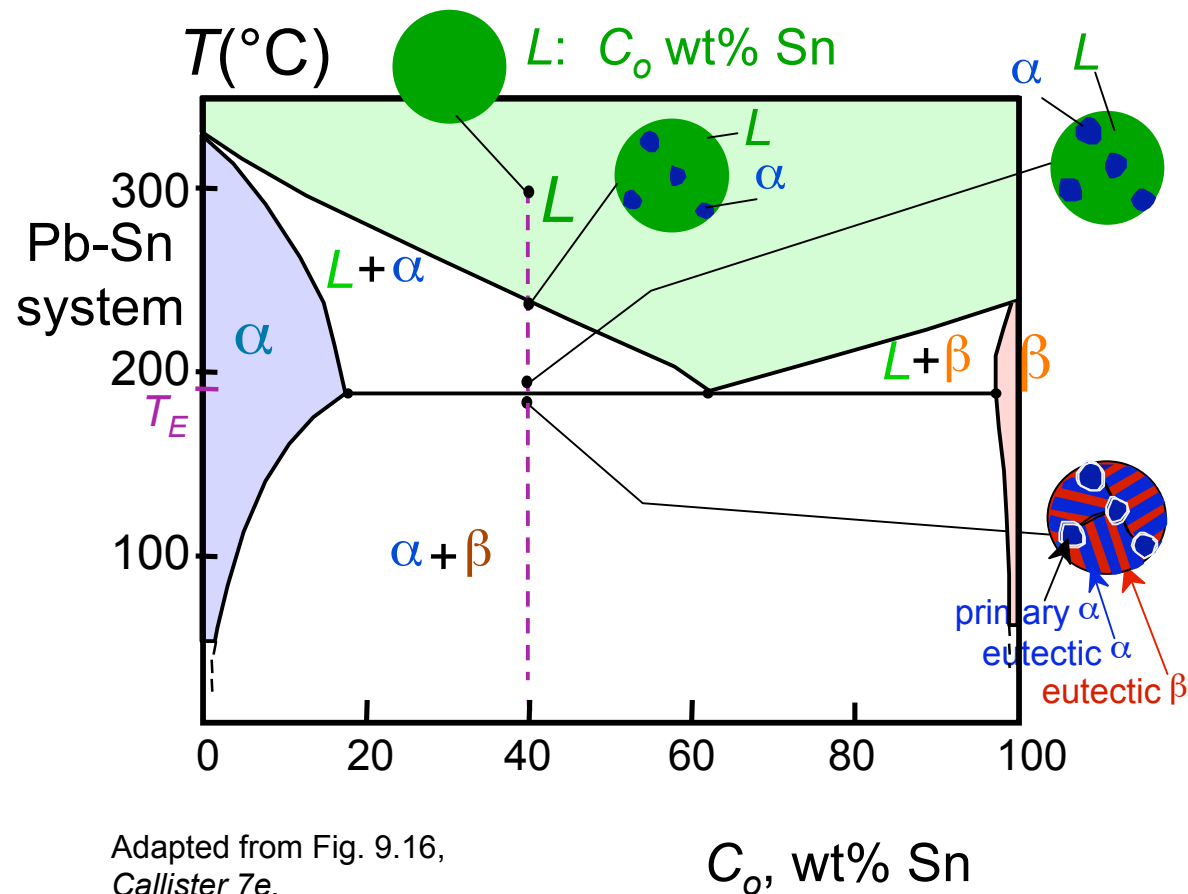


160 μm

Adapted from Fig. 9.14, Callister 7e.

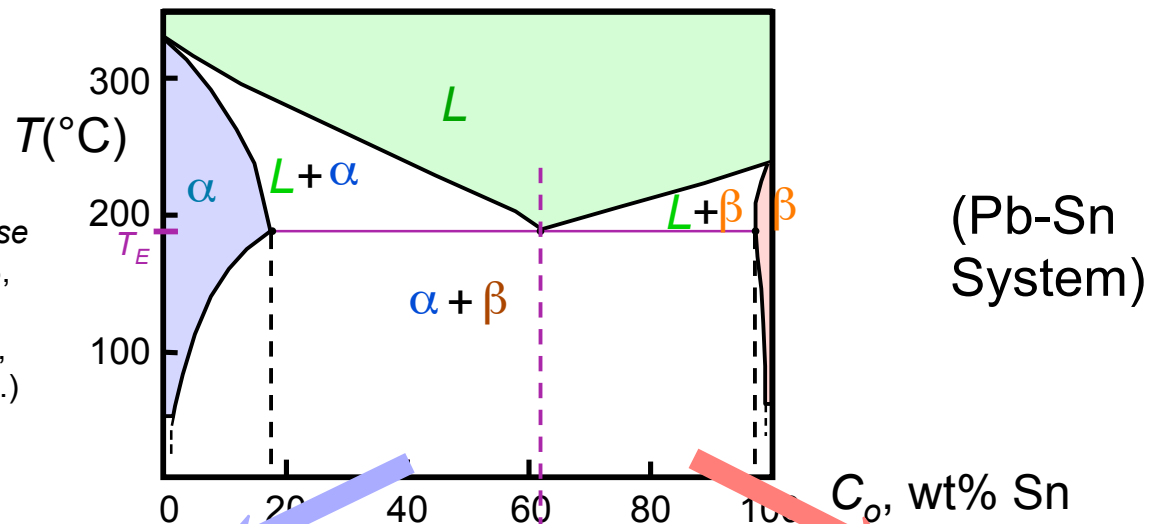
Microstructures in eutectic systems

- 18.3 wt% Sn < C_o < 61.9 wt% Sn
- Result: α crystals and a eutectic microstructure

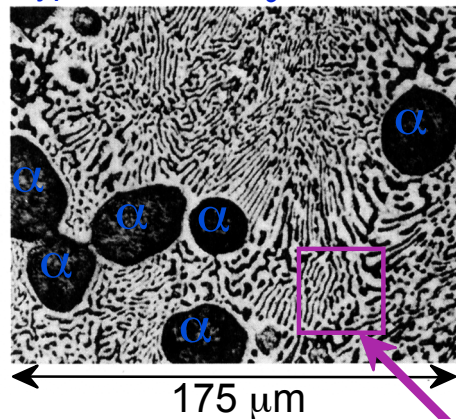


Hypoeutectic & hypereutectic

Adapted from Fig. 9.8, *Callister 7e*. (Fig. 9.8 adapted from *Binary Phase Diagrams*, 2nd ed., Vol. 3, T.B. Massalski (Editor-in-Chief), ASM International, Materials Park, OH, 1990.)



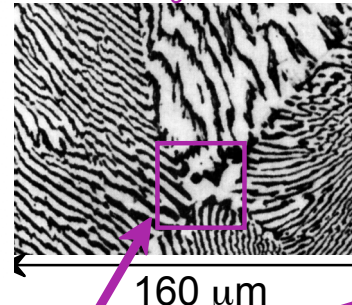
hypoeutectic: $C_0 = 50 \text{ wt\% Sn}$



Adapted from Fig. 9.17, *Callister 7e*.

eutectic
61.9

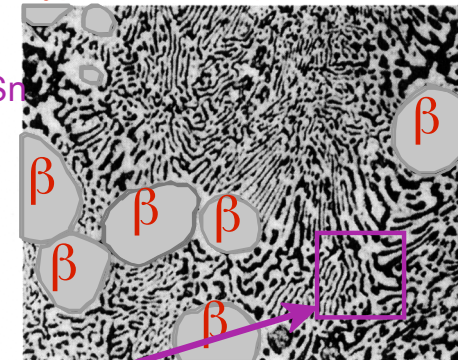
eutectic: $C_0 = 61.9 \text{ wt\% Sn}$



eutectic micro-constituent

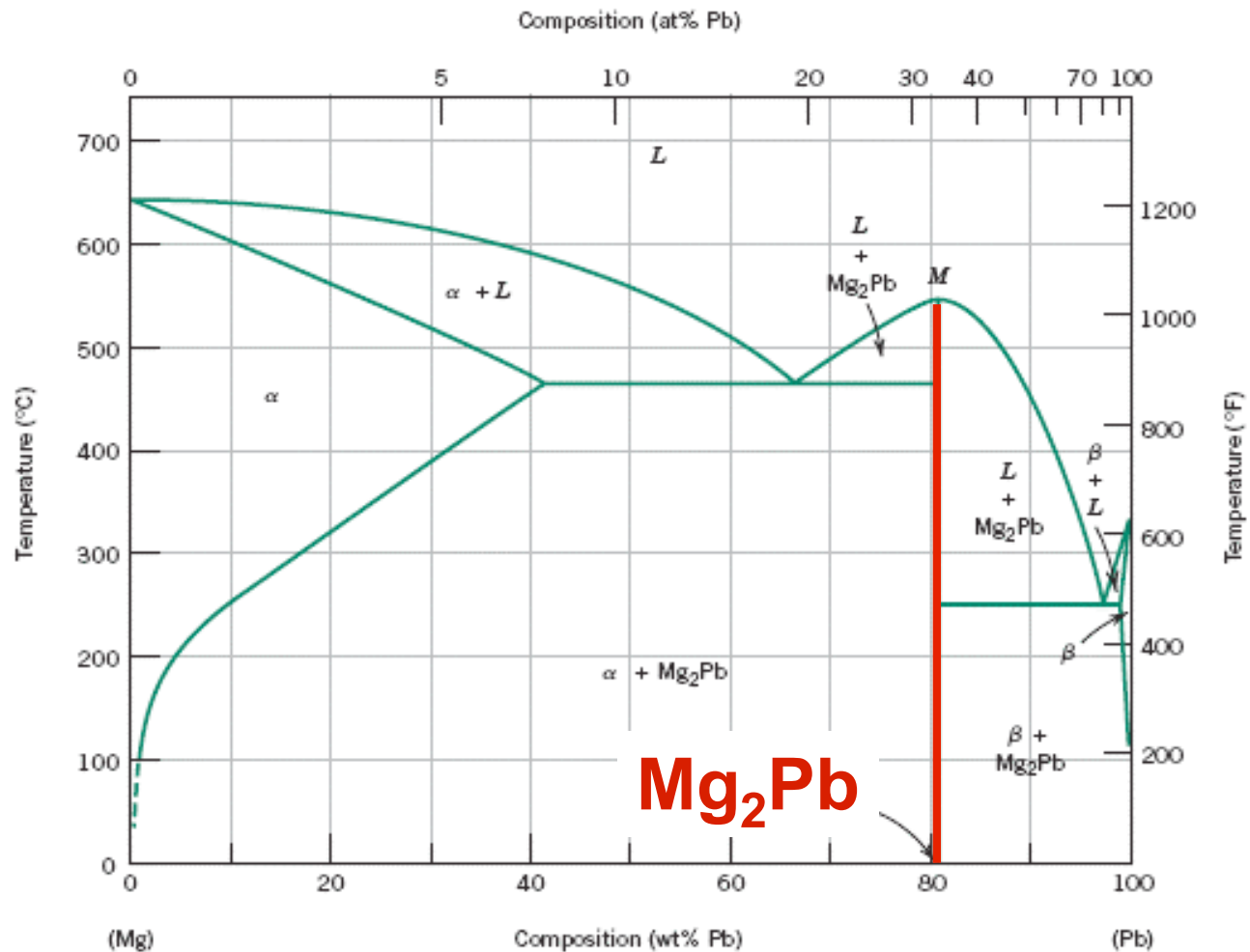
Adapted from Fig. 9.14, *Callister 7e*.

hypereutectic: (illustration only)



Adapted from Fig. 9.17, *Callister 7e*. (Illustration only)

Intermetallic compounds

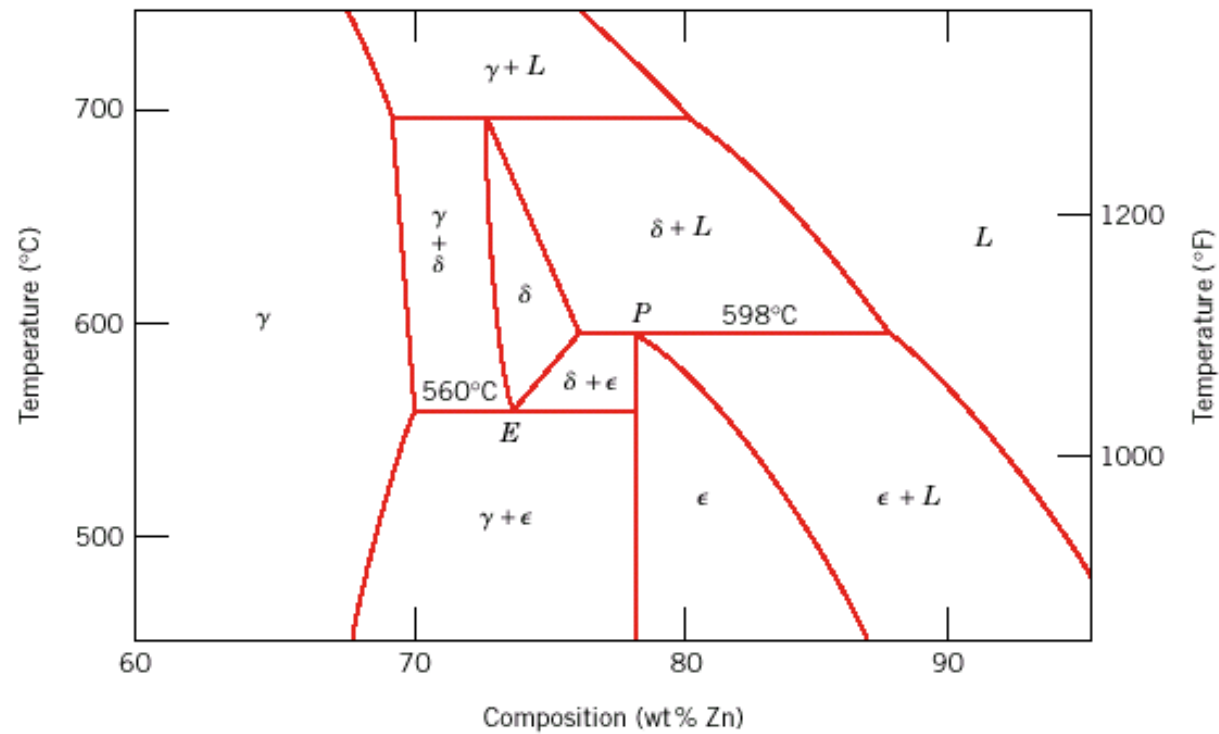


Adapted from
Fig. 9.20, Callister 7e.

Note: intermetallic compound forms a line - not an area - because stoichiometry (i.e. composition) is exact.

Peritectic & eutectoid

- Cu-Zn Phase diagram

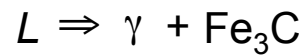


Adapted from
Fig. 9.21, Callister 7e.

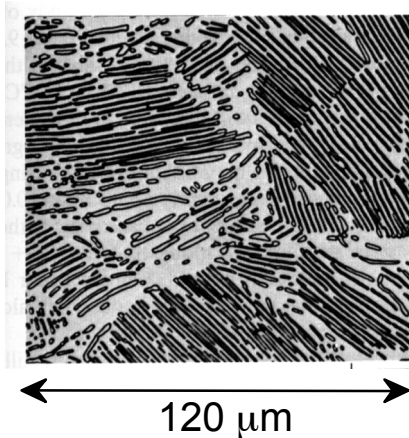
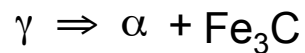
Fe-C phase diagram

- 2 important points

-Eutectic (A):

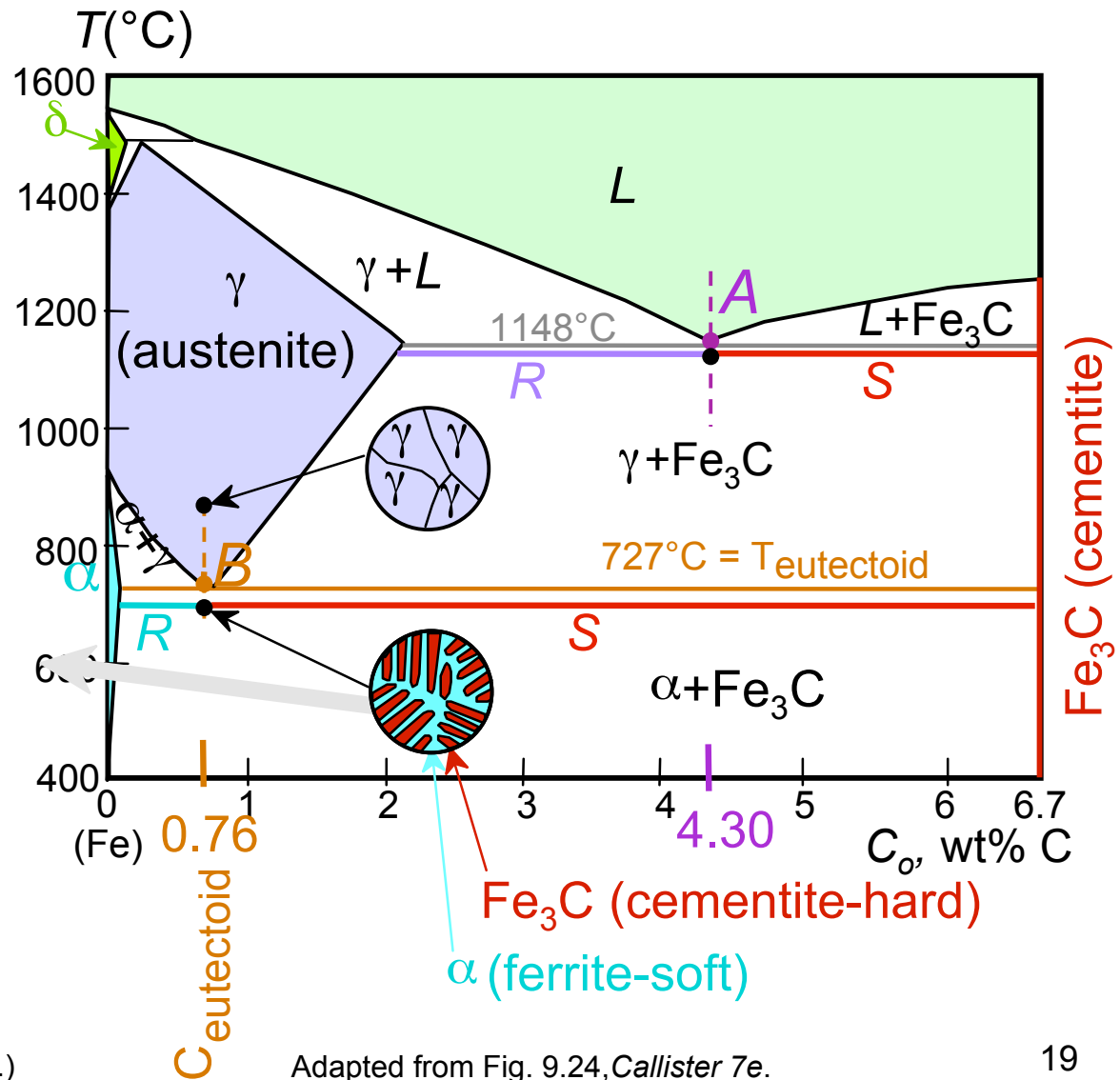


-Eutectoid (B):

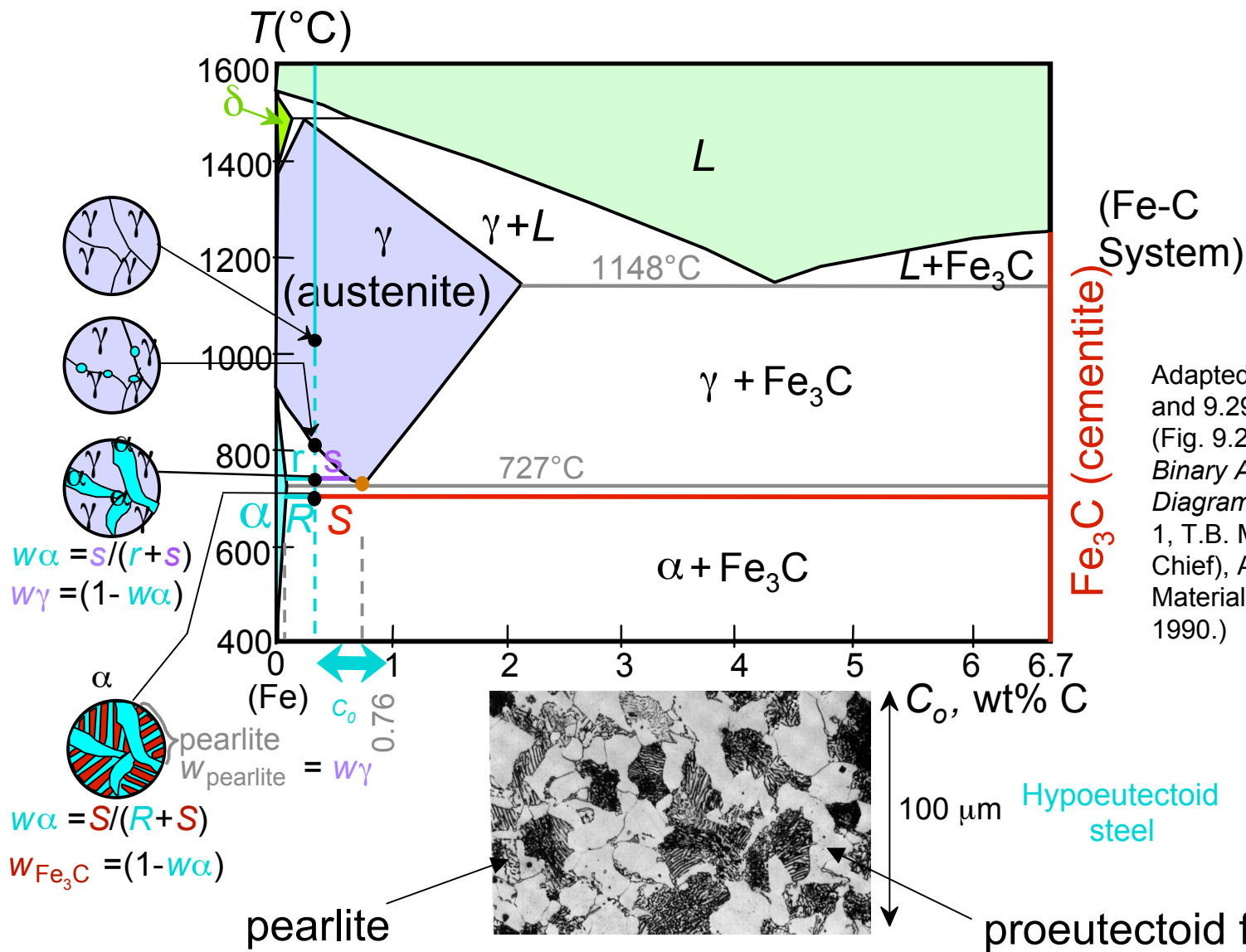


Result: Pearlite = alternating layers of α and Fe_3C phases

(Adapted from Fig. 9.27, Callister 7e.)

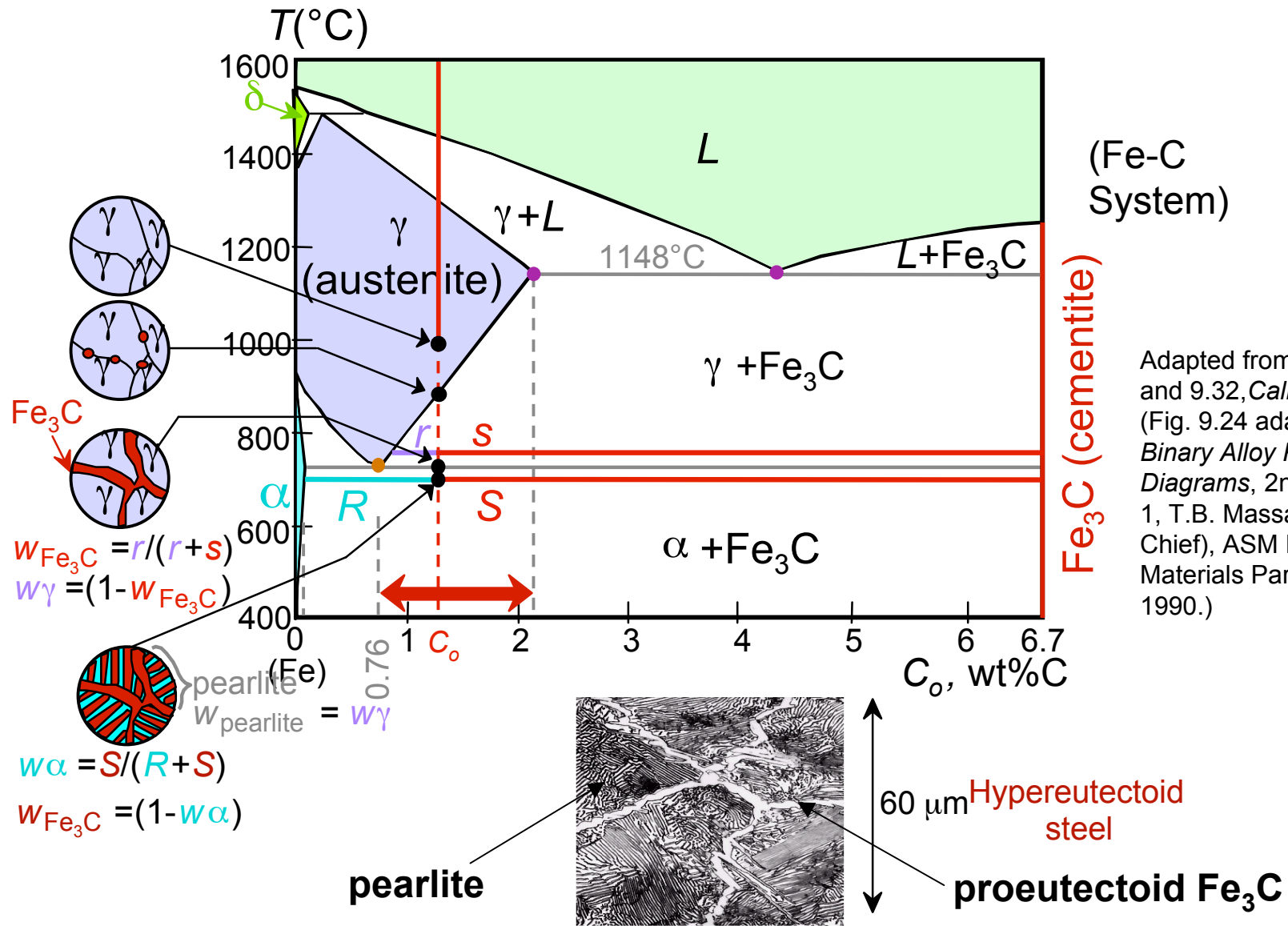


Hypoeutectoid steel



Adapted from Fig. 9.30, *Callister 7e*.

Hypereutectoid steel



Adapted from Fig. 9.33, *Callister 7e*.