PHASE EQUILIBRIUM

- **Component**: is either pure metal and/or compound of which an alloy is composed. They refer to the independent chemical species that comprise the system.

- **Solid Solution**: It consists of atoms of at least two different types where solute atoms occupy either substitutional or interstitial positions in the solvent lattice and the crystal structure of the solvent is maintained.

- **Solubility limit**: for almost all alloy systems, at specific temperature, a maximum of solute atoms can dissolve in solvent phase to form a solid solution. The limit is known as solubility limit.

- **Phase**: defined as a homogenous portion of a system that has uniform physical and chemical characteristics i.e. it is a physically distinct from other phases, chemically homogenous and mechanically separable portion of a system.

- **Variable of a system**: theses include two external variables namely temperature and pressure along with internal variable such as composition © and number of phases (P). Number of independent variable among these gives the degree of freedom (F).

- They are given by Gibbs Phase rule

$$P + F = C + 2$$

EQUILIBRIUM PHASE DIAGRAM

- A diagram that depicts existence of different phases of a system under equilibrium is termed as *phase diagram*. Equilibrium phase diagrams represent the relationships between temperature and the compositions and the quantities of phases at equilibrium. In general practice it is sufficient to consider only solid and liquid phases, thus pressure is assumed to be constant (1 *atm.) in most applications.*

- Important information obtainable from a phase diagram can be summarized as follows:

- To show phases are present at different compositions and temperatures under slow cooling (equilibrium) conditions.
- To indicate equilibrium solid solubility of one element/compound in another.
- To indicate temperature at which an alloy starts to solidify and the range of solidification.
- To indicate the temperature at which different phases start to melt.
- Amount of each phase in a two-phase mixture can be obtained.

- A phase diagram is actually a collection of solubility limit curves. Set of solubility curves that represents locus of temperatures above which all compositions are liquid are called *liquidus,* while *solidus* represents set of solubility curves that denotes the locus of temperatures below which all compositions are solid. Every phase diagram for two or more components must show a liquidus and a solidus. Phase diagrams are classified based on the number of components in the system. Single component systems have unary diagrams, two-component systems have binary diagrams, three-component systems are represented by ternary diagrams, and so on. When more than two components are present, phase diagrams become extremely complicated and difficult to represent.

UNARY PHASE DIAGRAM

- In these systems there is no composition change *(C=1), thus only variables are temperature and pressure. Thus in region of single phase two variables (temperature and pressure) can be varied independently. If two phases coexist then, according to Phase rule, either temperature or pressure can be varied independently, but not both. At triple points, three phases can coexist at a particular set of temperature and pressure. At these points, neither temperature nor the pressure can be changed without disrupting the equilibrium i.e. one of the phases may disappear.*
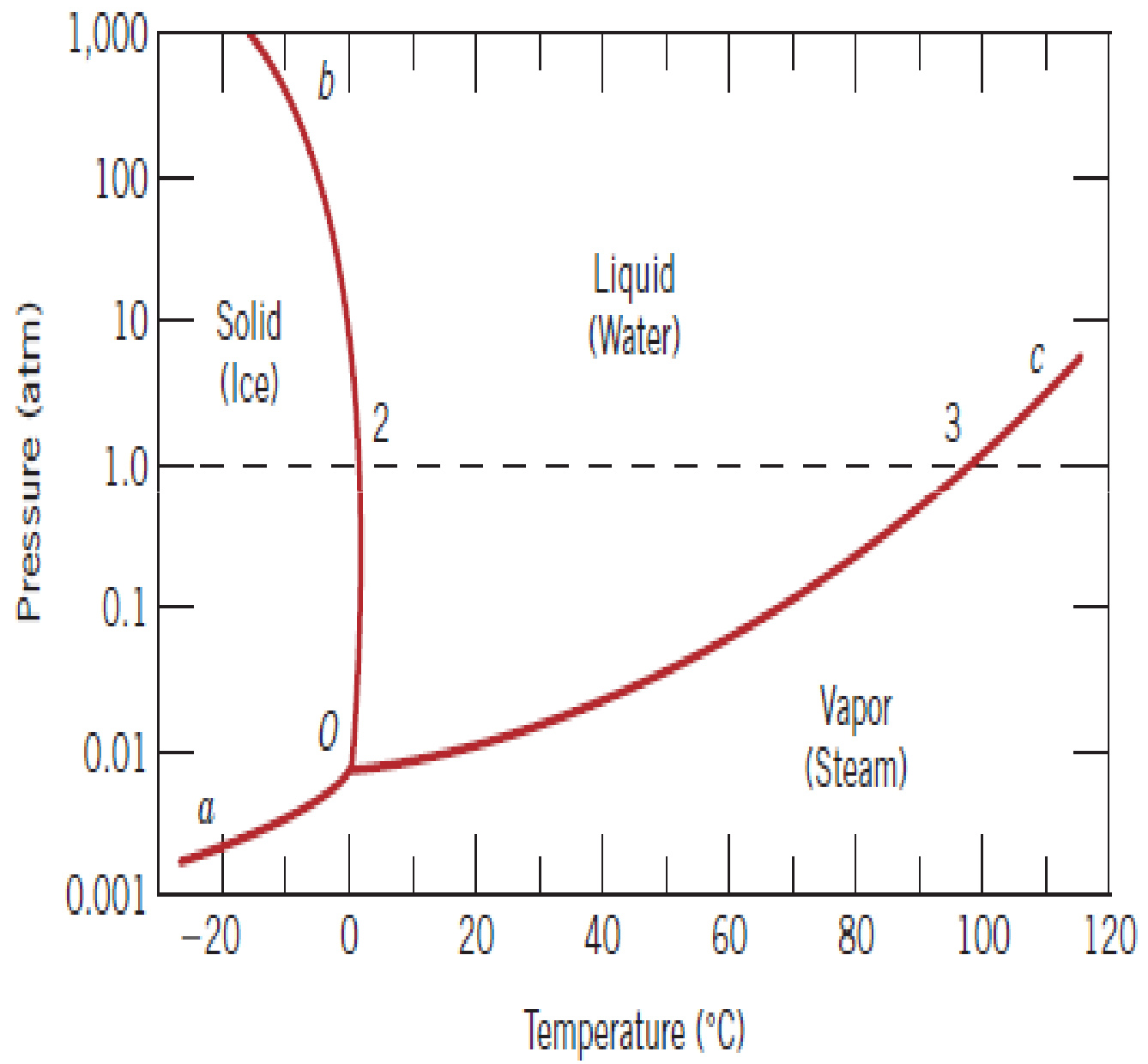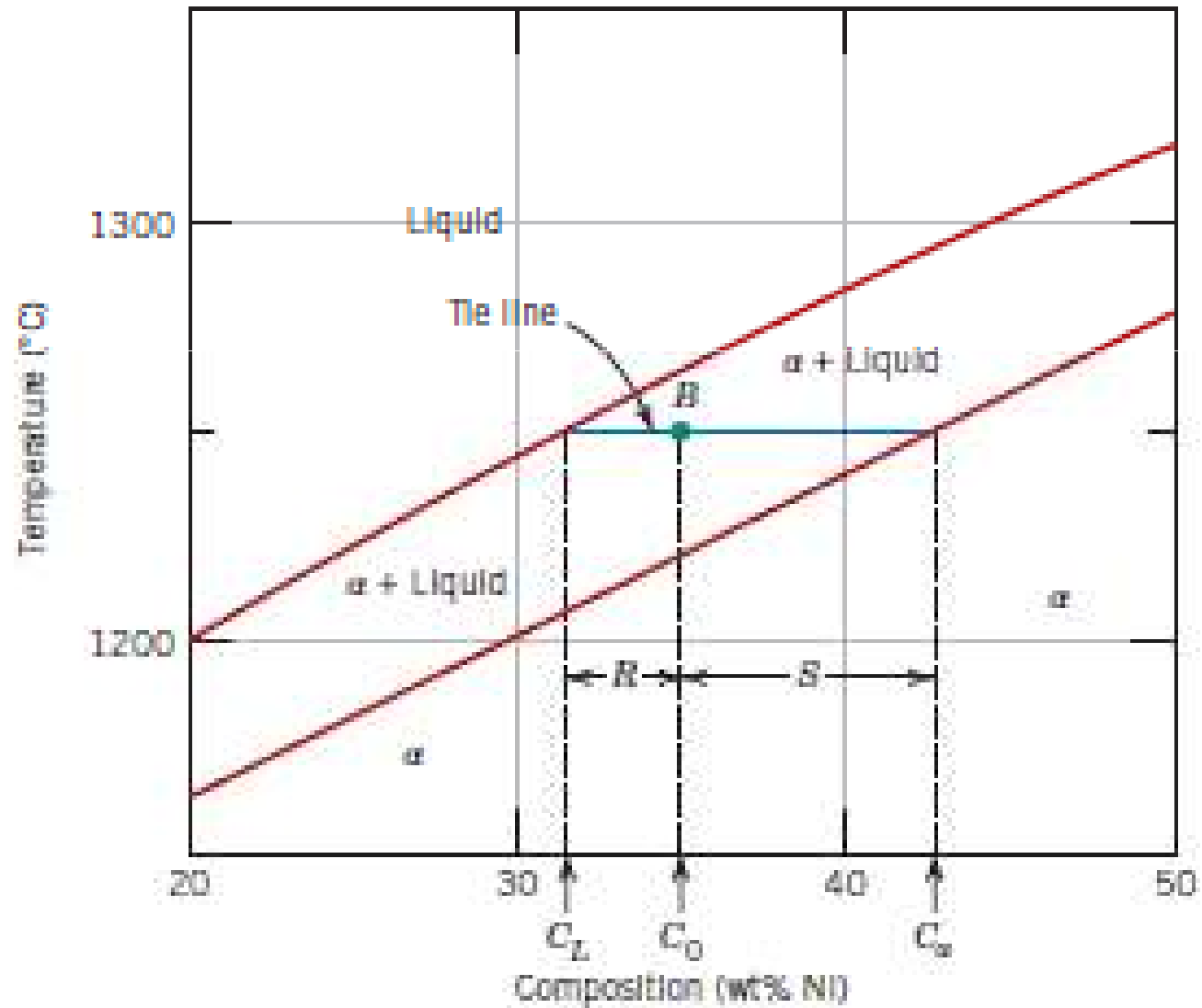
BINARY PHASE DIAGRAM

- Binary phase diagrams are maps that represent the relationships between temperature and the compositions and quantities of phases at equilibrium, which influence the microstructure of an alloy. Many microstructures develop from phase transformations, the changes that occur when the temperature is altered (ordinarily upon cooling).This may involve the transition from one phase to another, or the appearance or disappearance of a phase. Binary phase diagrams are helpful in predicting phase transformations and the resulting microstructures, which may have equilibrium or non-equilibrium character.

Composition (at% Ni)

Temperature (°C)

Temperature (°F)

Liquid

1453°C

Liquidus line

Solidus line

α + L

• B

α

• A

1085°C

(Cu)

Composition (wt% Ni)

(Ni)
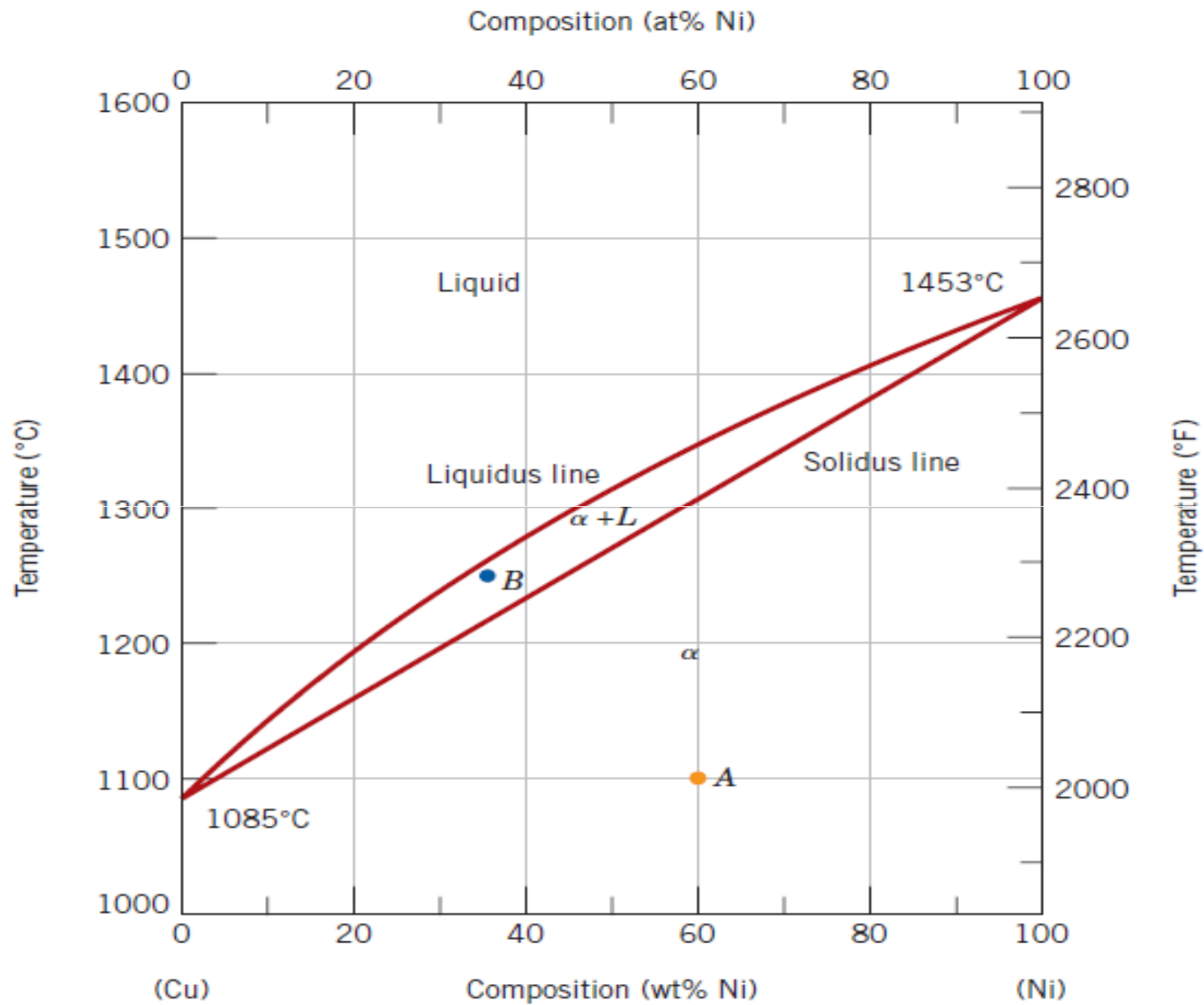
DETERMINATION OF PHASE AMOUNTS

- The tie line must be utilized in conjunction with a procedure that is often called the **lever rule,** *which is applied* as follows:
- 1. The tie line is constructed across the two-phase region at the temperature of the alloy.
- 2. The overall alloy composition is located on the tie line.
- 3. The fraction of one phase is computed by taking the length of tie line from the overall alloy composition to the phase boundary for the *other phase, and* dividing by the total tie line length.
- 4. The fraction of the other phase determined in the same manner.

The tie line has been constructed that was used for the determination of and *L phase compositions. Let* the overall alloy composition be located along the tie line and denoted as and mass fractions be represented by W_L and W_a for the respective phases. From the lever rule, W_L may be computed according to
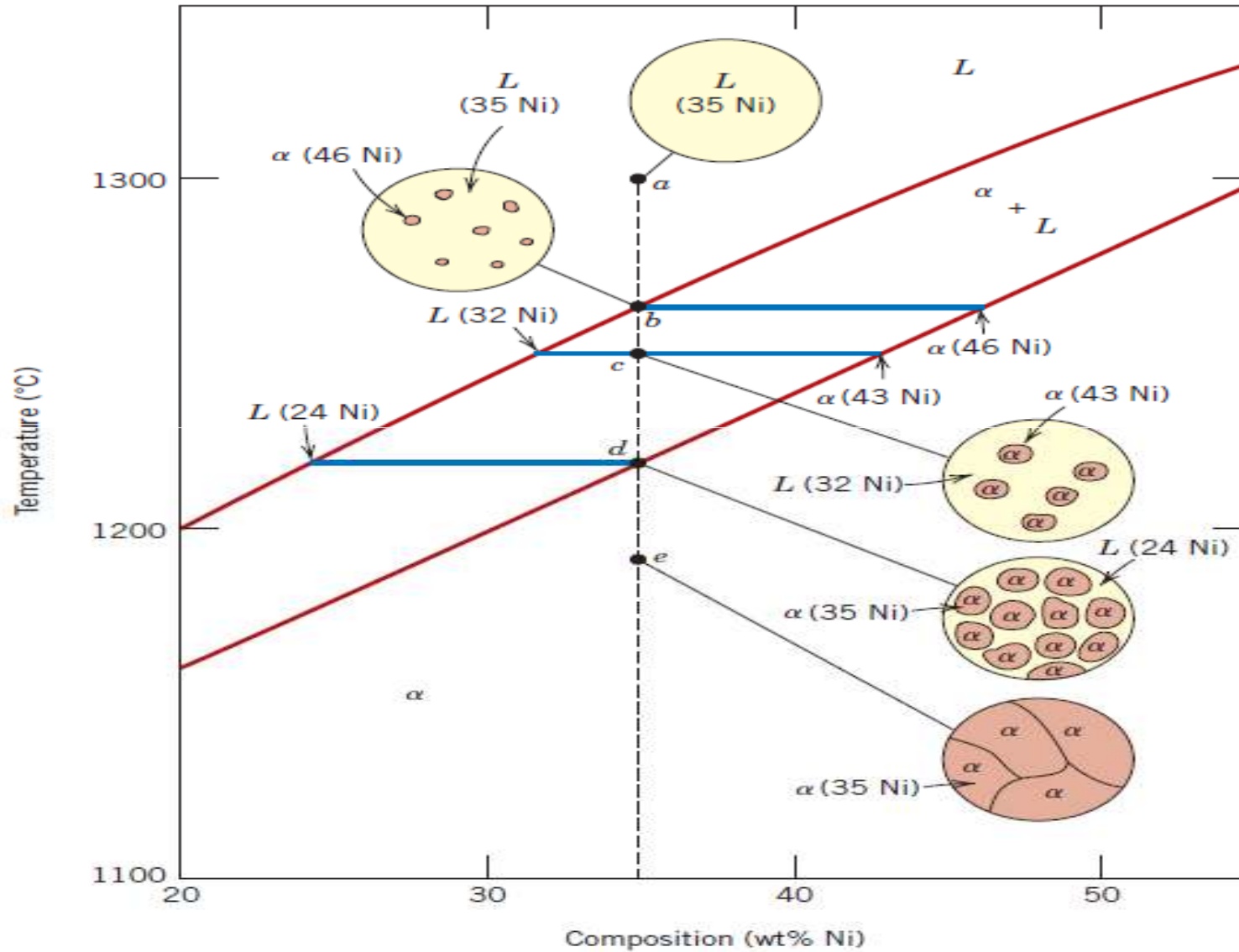
$$W_L = \frac{S}{R + S}$$

or, by subtracting compositions,

$$W_L = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$
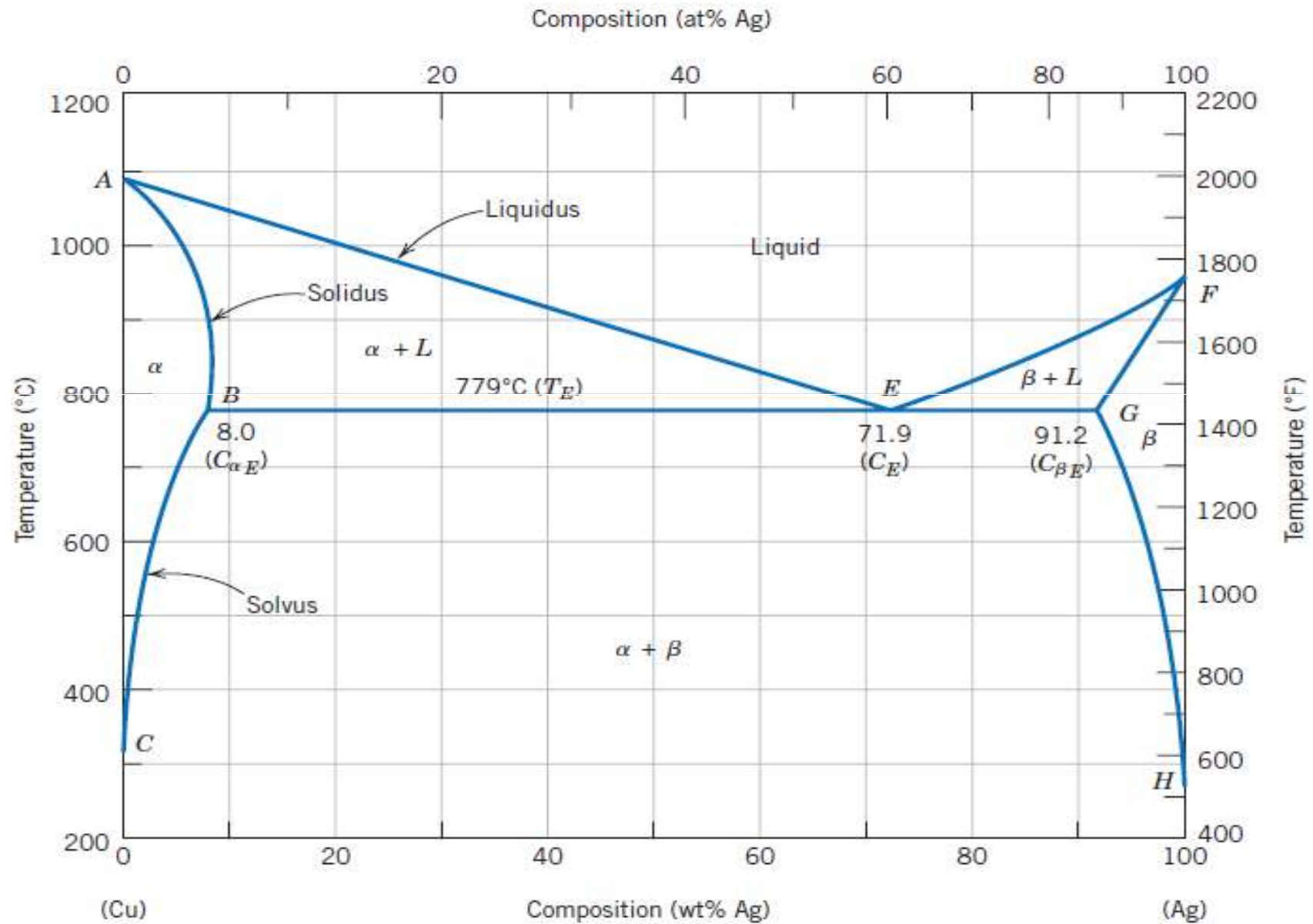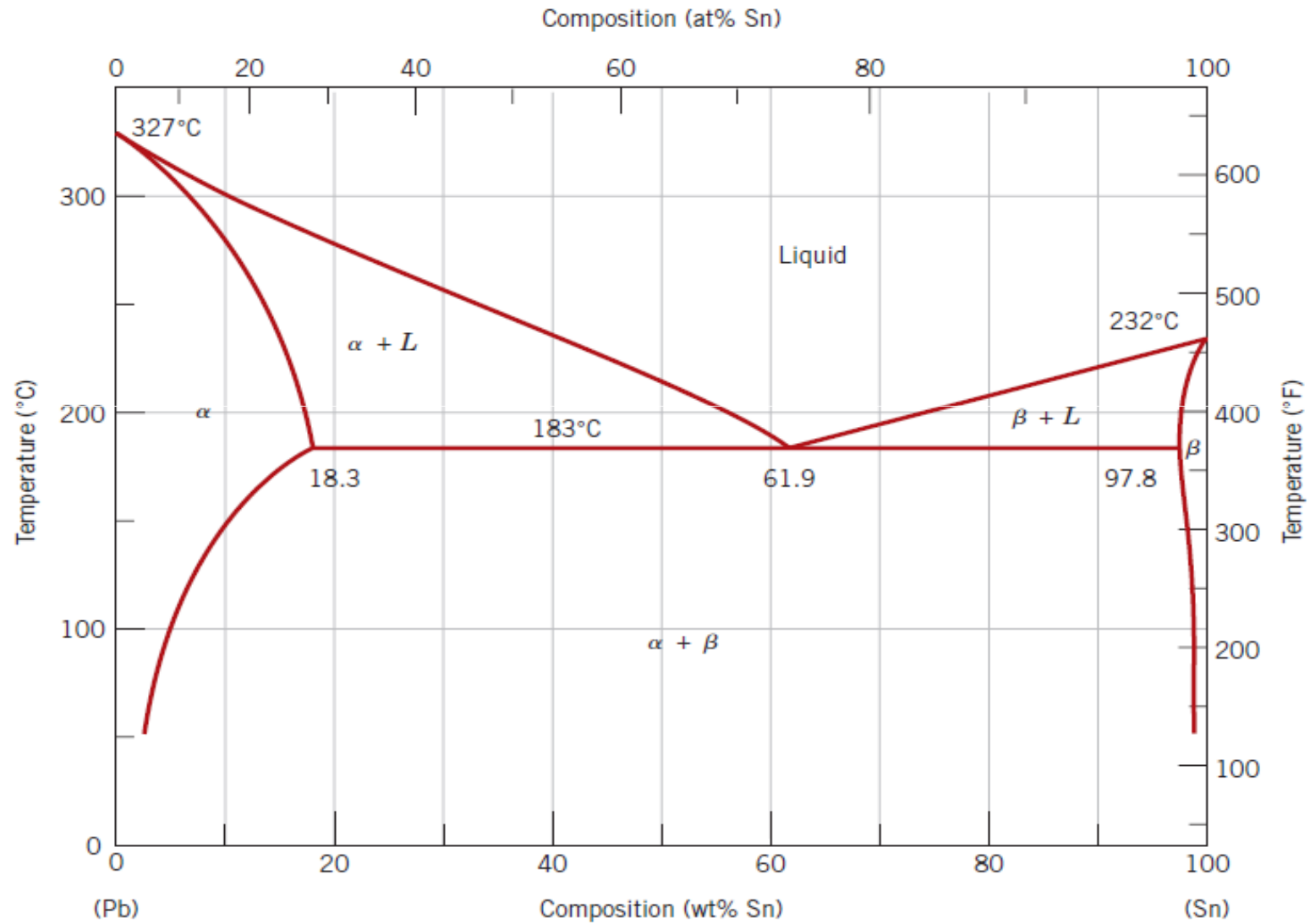
DEVELOPMENT OF MICROSTRUCTURE IN ISOMORPHOUS ALLOYS

BINARY EUTECTIC SYSTEMS

○ A number of features of this phase diagram are important: First, three single-phase regions are found on the diagram: α, b, and liquid. The α phase is a solid solution rich in copper; it has silver as the solute component and an FCC crystal structure. The b -phase solid solution also has an FCC structure, but copper is the solute. Pure copper and pure silver are also considered to be α and b phases, respectively.

○ Thus, the solubility in each of these solid phases is limited, in that at any temperature below line *BEG only a limited concentration of silver will dissolve in* Copper and similarly for copper in silver.
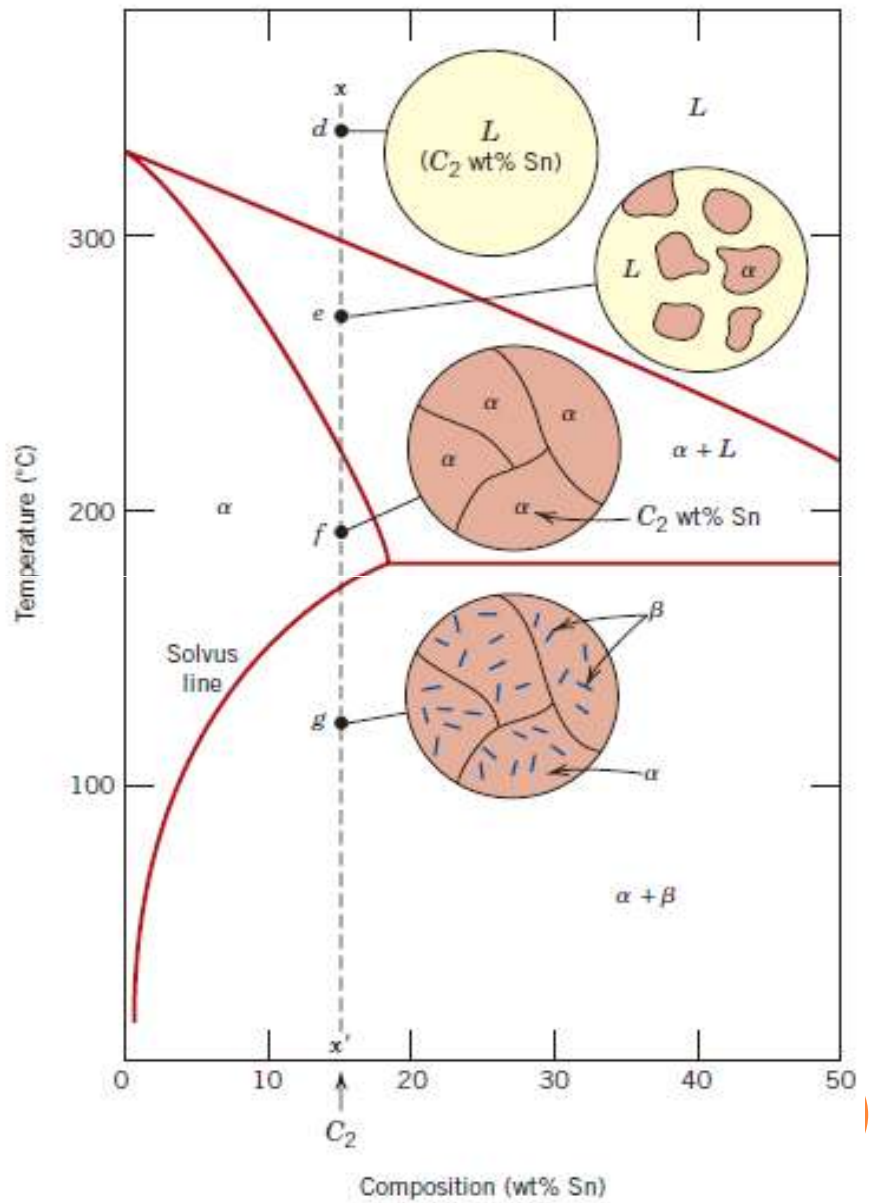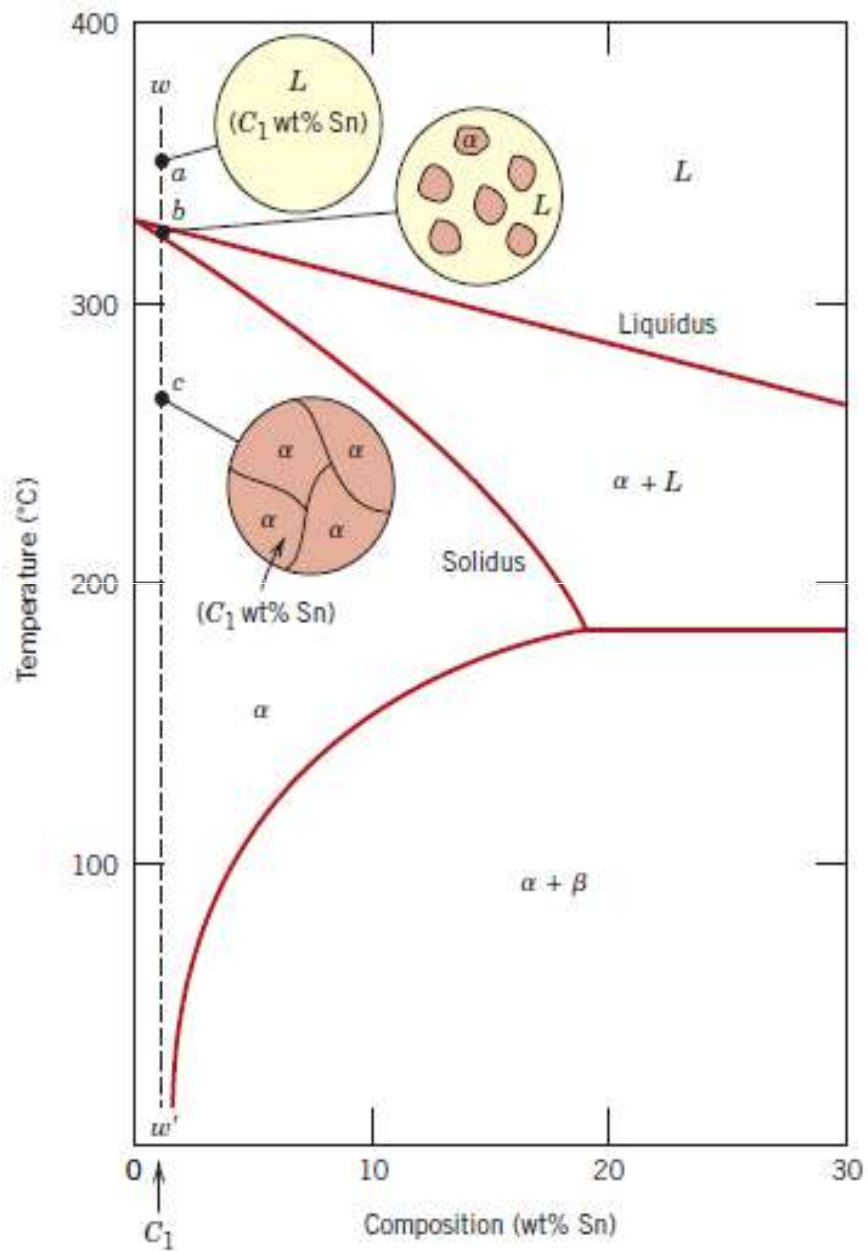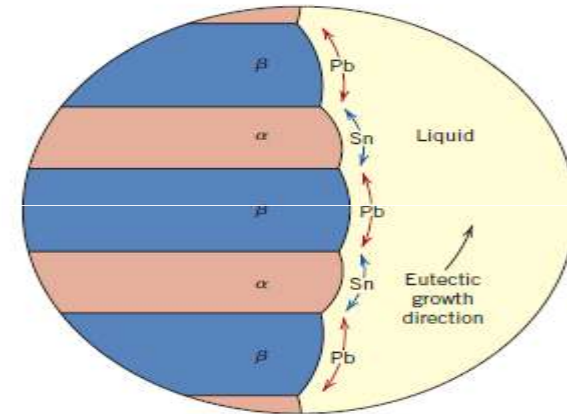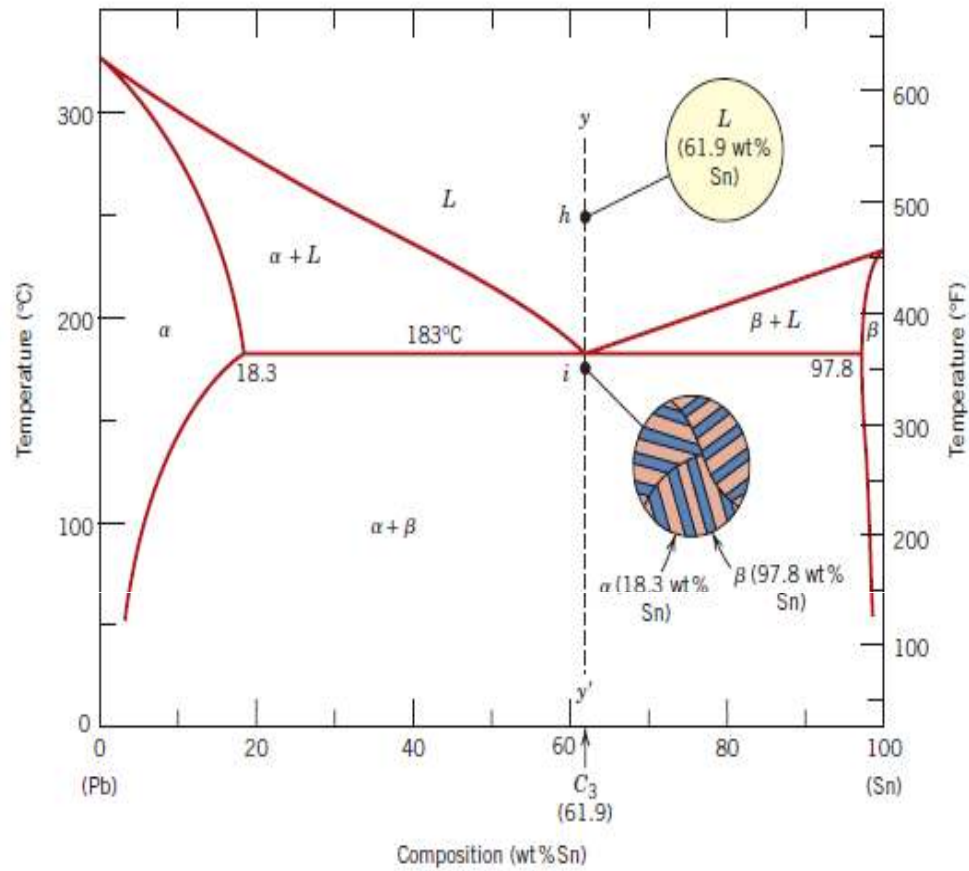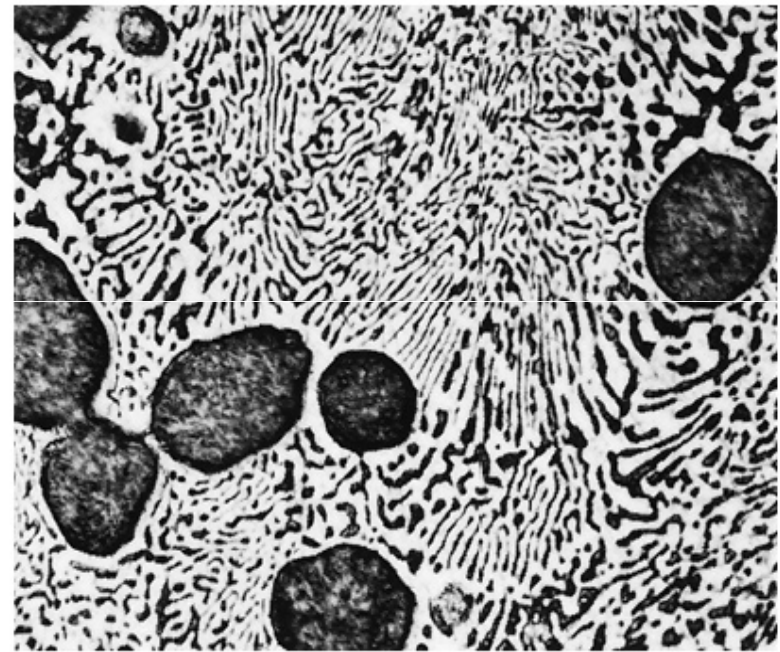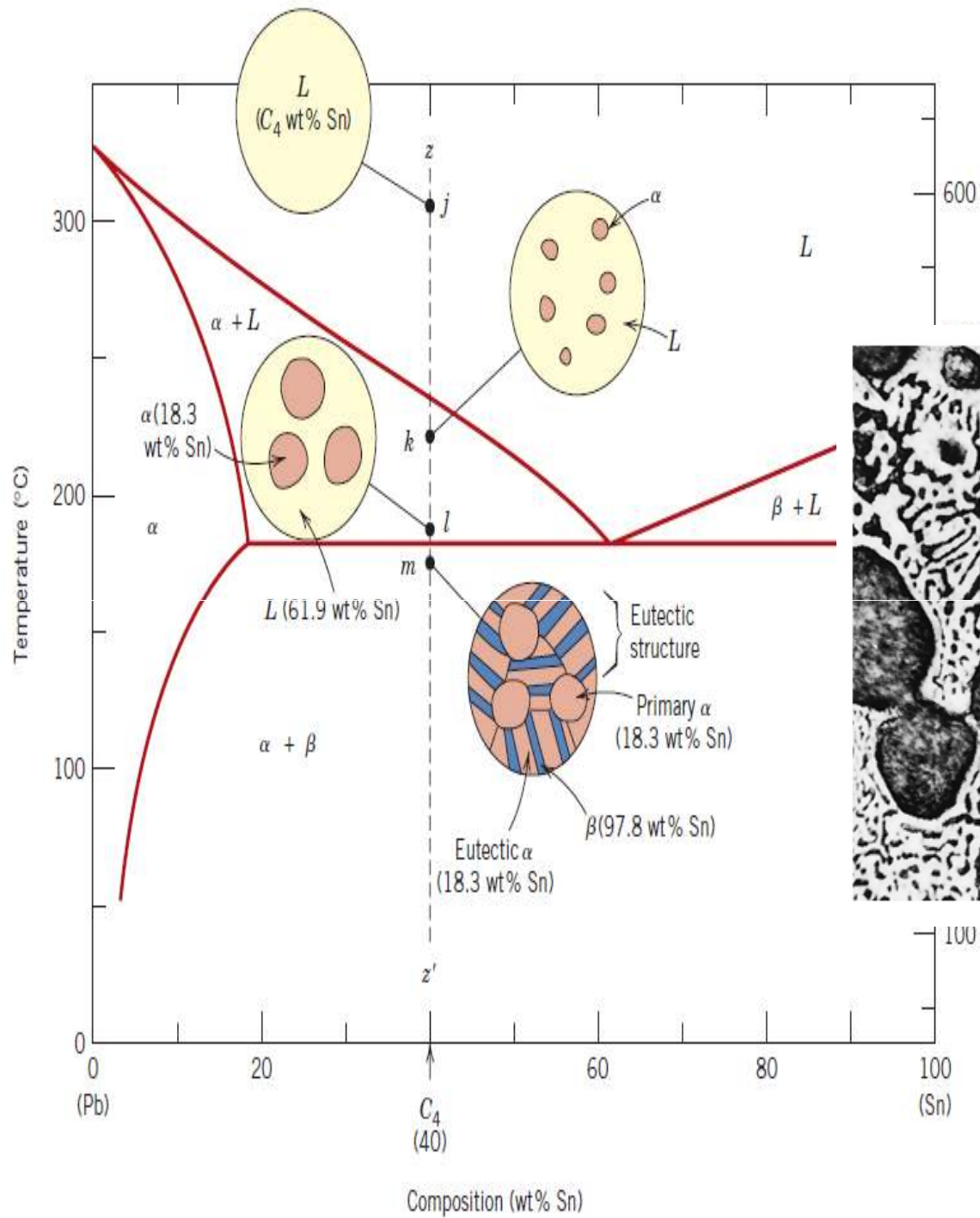
CU-AG BINARY EUTECTIC SYSTEM

Composition (at% Ag)

PB-SN BINARY EUTECTIC SYSTEM

Left diagram labels: Temperature (°C), Composition (wt% Sn), 400, 300, 200, 100, 0, 10, 20, 30

w, a, b, c, L (C₁ wt% Sn), Liquidus, α + L, Solidus, α, (C₁ wt% Sn), α + β, w', C₁

Right diagram labels: Temperature (°C), Composition (wt% Sn), 300, 200, 100, 0, 10, 20, 30, 40, 50

x, d, e, f, g, L (C₂ wt% Sn), L, α, α + L, C₂ wt% Sn, β, α, Solvus line, α + β, x', C₂

L
(C₄ wt% Sn)

z

j

600

α

L

L

$\alpha + L$

α(18.3
wt% Sn)

k

300

200

Temperature (°C)

α

l

$\beta + L$

m

L (61.9 wt% Sn)

Eutectic
structure

Primary α
(18.3 wt% Sn)

100

$\alpha + \beta$

β(97.8 wt% Sn)

Eutectic α
(18.3 wt% Sn)

100

z'

0

0
(Pb)

20
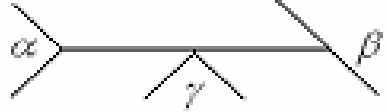
C_4
(40)

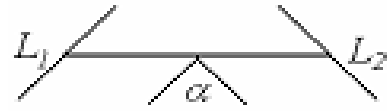60

80

100
(Sn)

Composition (wt% Sn)

IRON-CARBON SYSTEM

o Of all binary alloy systems, the one that is possibly the most important is that for iron and carbon. Both steels and cast irons, primary structural materials in every technologically advanced culture, are essentially iron–carbon alloys. Pure iron, upon heating, experiences two changes in crystal structure before it melts. At room temperature the stable form, called **ferrite,** or α iron, has a BCC crystal structure. Ferrite experiences a polymorphic transformation to FCC **austenite,** or γ iron, at 912°C or (1674F). This austenite persists to 1394°C (2541F), at which temperature the FCC austenite reverts back to a BCC phase known as δ ferrite, which finally melts at 1538°C. All these changes are apparent along the left vertical axis of the phase diagram.

INVARIANT REACTION

Reaction	Symbolic equation	Schematic presentation	Example
Eutectic	$L \rightarrow \alpha + \beta$		Fe-C, 4.27% C, 1147 C
Eutectoid	$\alpha \rightarrow \beta + \gamma$		Fe-C, 0.80% C, 723 C
Peritectic	$L + \alpha \rightarrow \beta$		Fe-C, 0.16%C, 1495 C
Peritectoid	$\alpha + \beta \rightarrow \gamma$		
Monotectic	$L_1 \rightarrow L_2 + \alpha$		Fe-C, 0.51%C, 1495 C
Monotectoid	$\alpha_1 \rightarrow \alpha_2 + \beta$		
Syntectic	$L_1 + L_2 \rightarrow \alpha$		

Fe-C binary system – Phase transformations