TA201A
Manufacturing Processes

Week-3

23 Aug, 2022

2022-2023 Semester-I

Lecture 3

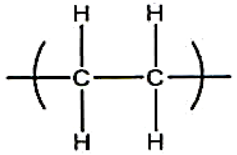
Polymers

Polymer = **poly** (many) + **mers** (part)

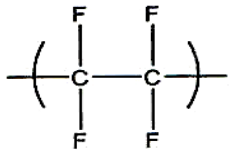
- Many repeating ***mers*** to form very large molecules held together by covalent bonding
- Main-C and
  Others- H, N, O, F, Si

- Secondary bonding
  (van der Waals)

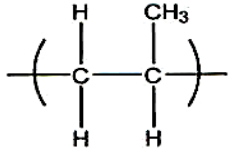
Repeat Units



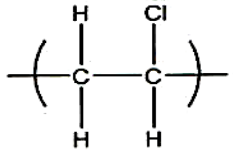
Polyethylene
(PE)



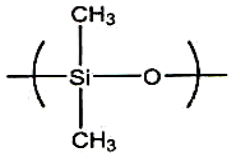
Polytetrafluoroethylene
(PTFE)



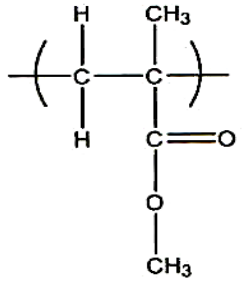
Polypropylene
(PP)



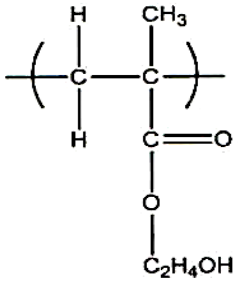
Polyvinylchloride
(PVC)



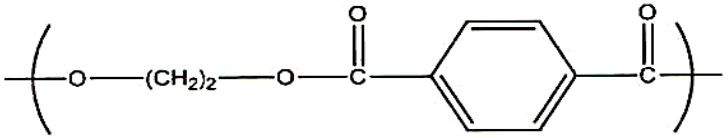
Polydimethylsiloxane
(PDMS)



Poly(methyl methacrylate)
(PMMA)



Poly(hydroxyethyl methacrylate)
(PHEMA)



Polyethyleneterephthalate
(PET)

Polymers: Classification

Polymers

- Plastics (Thermoplastics and Thermosetting)
- Rubbers (Elastomers)

- Thermoplastics: 70%
- Thermosets + Rubbers 30%

Polymers: Classification

Thermoplastics:

- They can be subjected to multiple heating and cooling cycles without substantially altering the molecular structure of the polymer.
- e.g., polyethylene, polystyrene, polyvinylchloride, and nylon

Thermosetting Polymers:

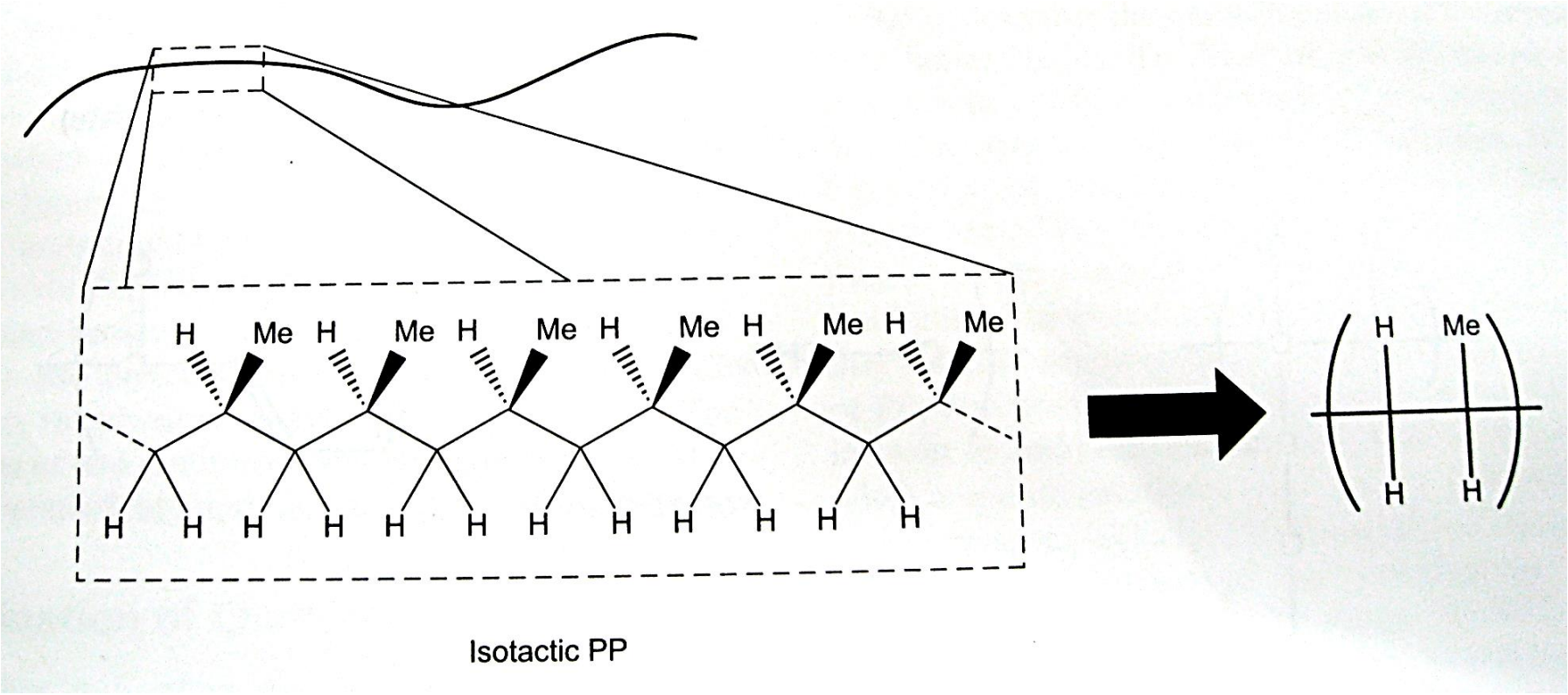
- Chemically transform (cure) into a rigid structure upon cooling from a heated plastic condition
- e.g., phenolics, amino resins, and epoxies

Elastomers

- Have large molecules with coiled structures
- The uncoiling and recoiling of the molecules when subjected to stress cycles
- e.g., rubber, neoprene, silicone, and polyurethane

Polymer: Molecular Structure

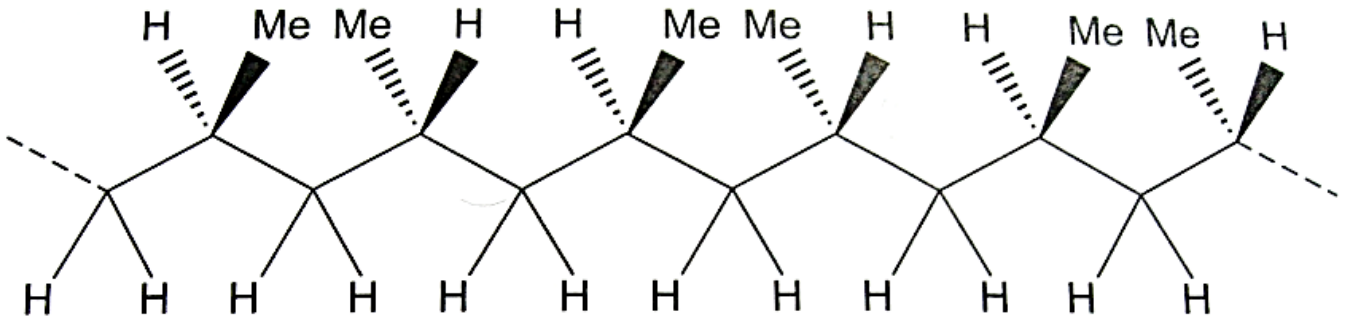
- Stereoregularity
  - Isotactic: all pendant groups on same side (strong)
  - Syndiotactic: atom groups alternate (strong, lower MP)
  - Atactic: groups are randomly along either side (no use)



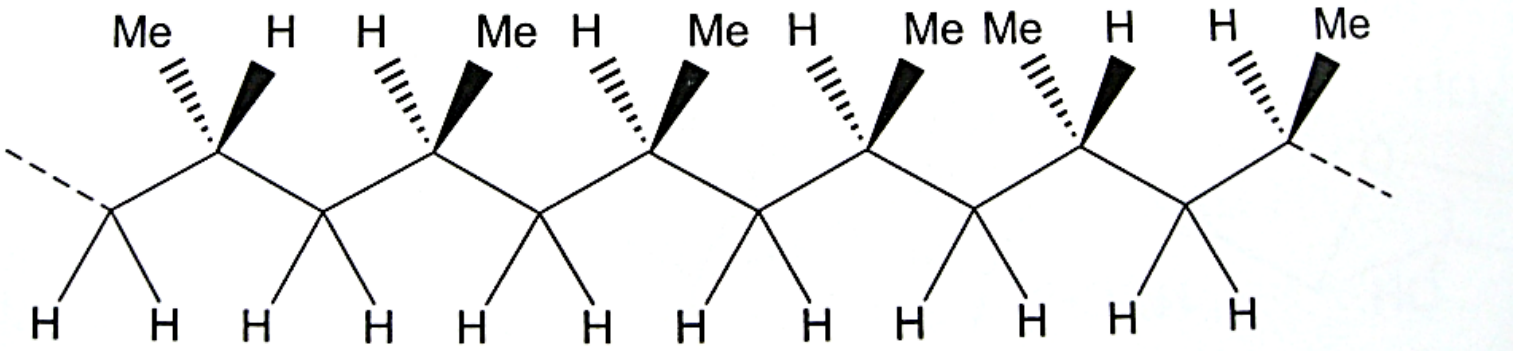
Isotactic PP

Polymer: Molecular Structure

- Stereoregularity



Syndiotactic PP



Atactic PP

Polymer: Molecular Structure

- Linear, branched and cross-linked polymers

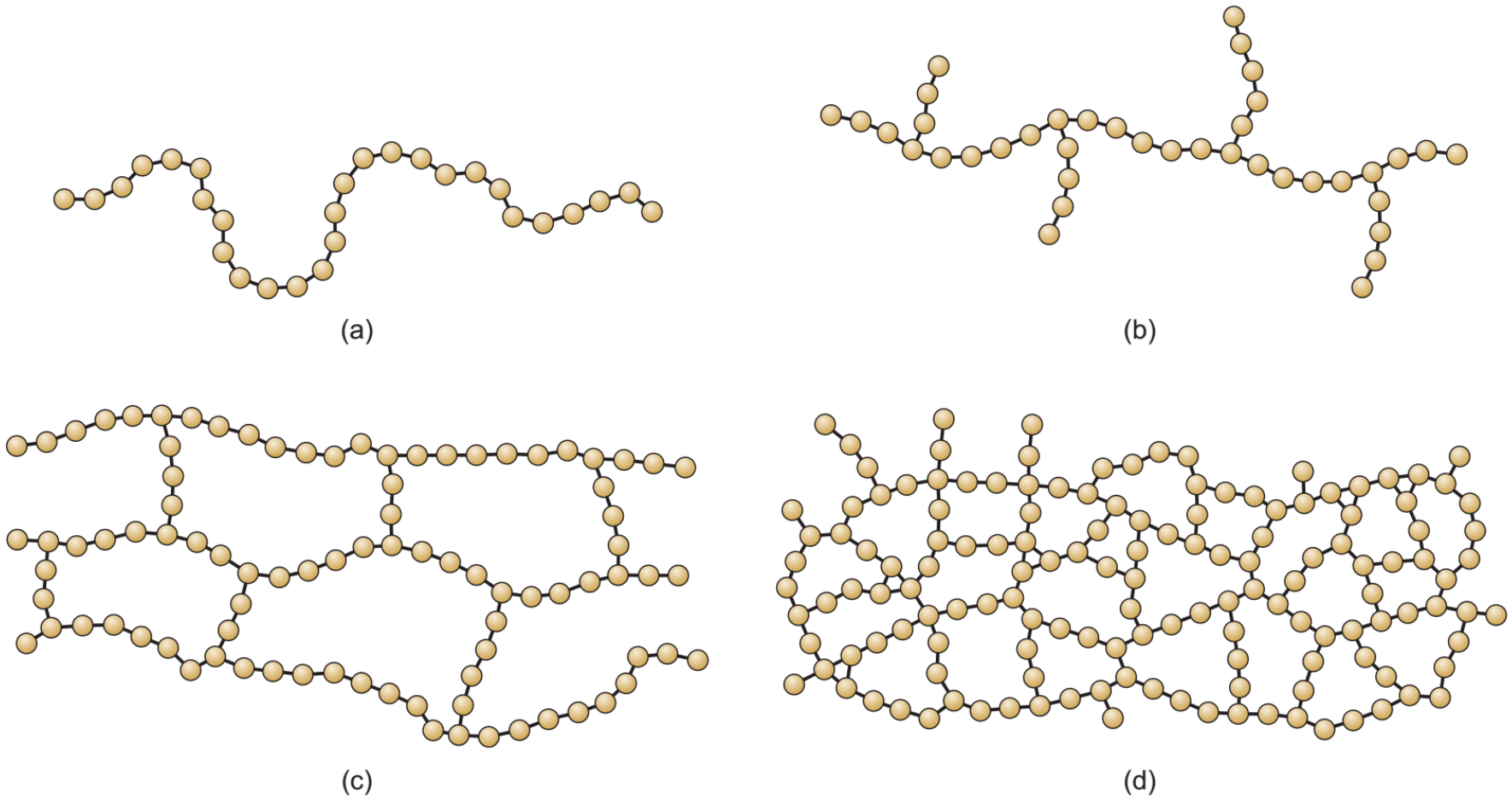
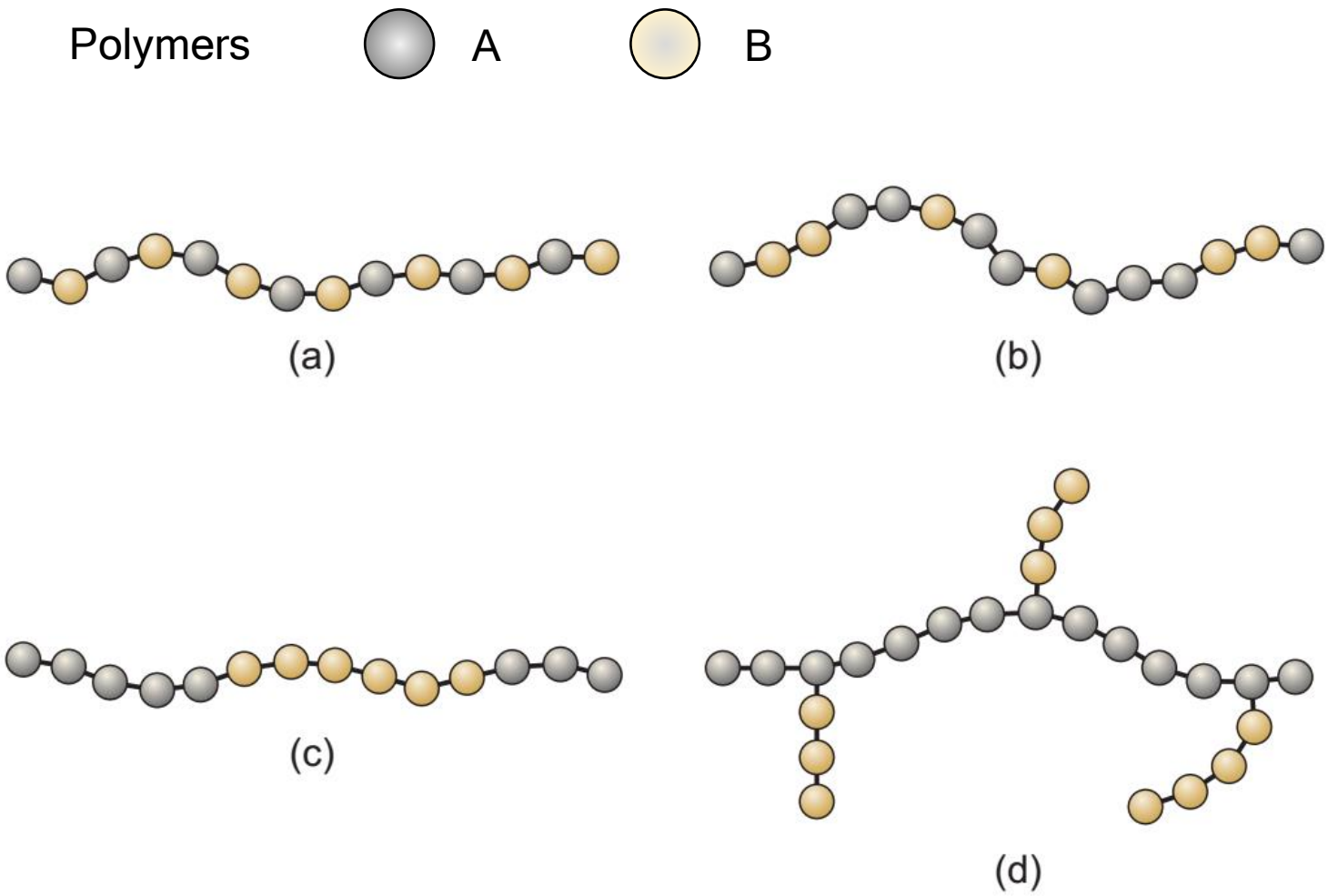


FIGURE 8.7 Various structures of polymer molecules: (a) linear, characteristic of thermoplastics; (b) branched; (c) loosely cross-linked as in an elastomer; and (d) tightly cross-linked or networked structure as in a thermoset.

Copolymers



Various structures of copolymers:
(a) alternating, (b) random, (c) block, and (d) graft.

Polymer: Molecular Structure

- Crystallinity
  - Degree of crystallinity: the proportion of crystallized material in the mass

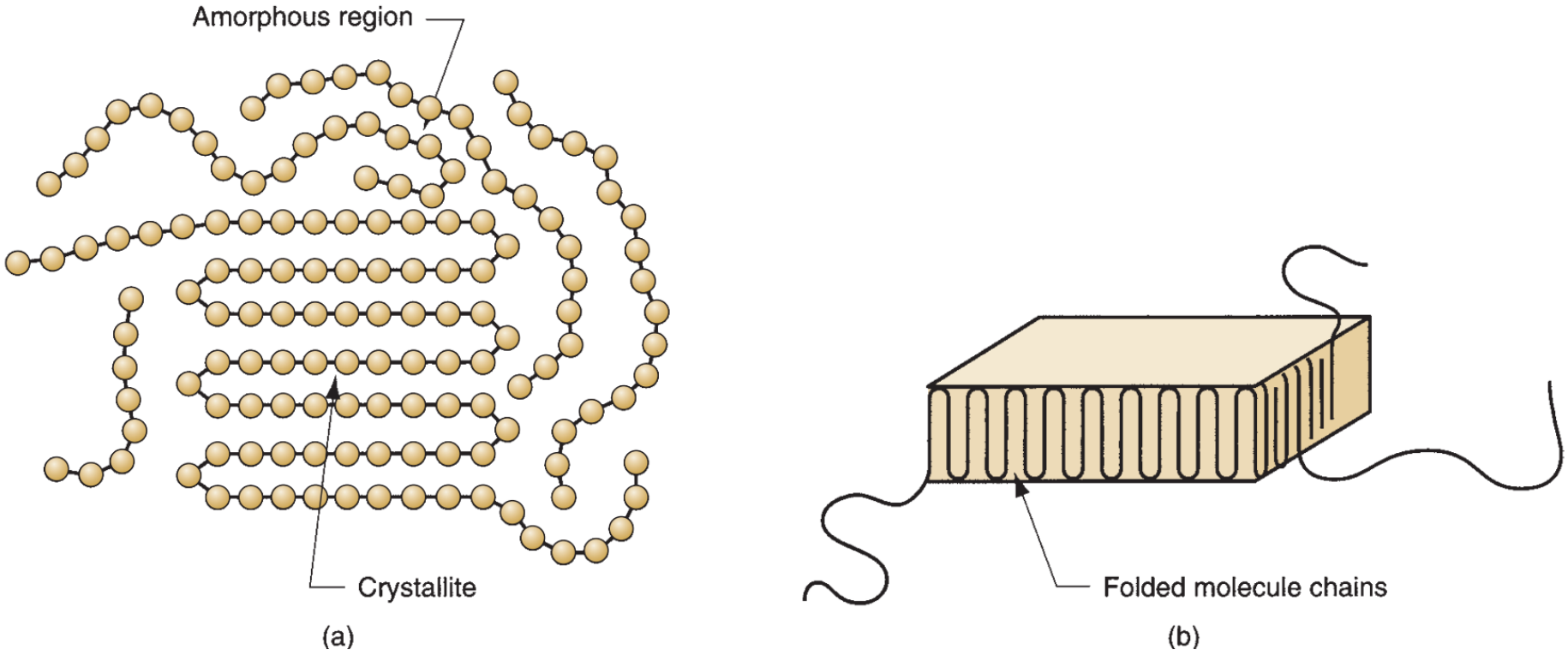


FIGURE 8.9 Crystallized regions in a polymer: (a) long molecules forming crystals randomly mixed in with the amorphous material; and (b) folded chain lamella, the typical form of a crystallized region.

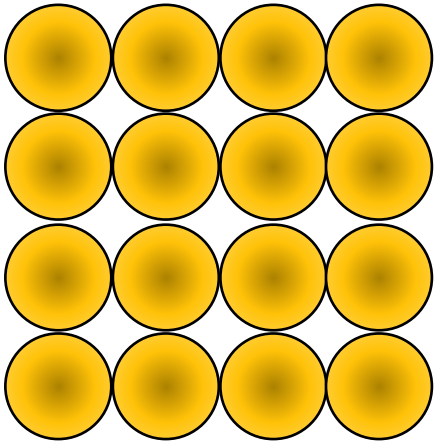
Polymer: Molecular Structure

- Increasing degree of crystallinity increases
  - Density
  - Stiffness, strength and toughness
  - Heat resistance
  - Opacity

TABLE • 8.2 Comparison of low-density polyethylene and high-density polyethylene.

Polyethylene Type	Low Density	High Density
Degree of crystallinity	55%	92%
Specific gravity	0.92	0.96
Modulus of elasticity	140 MPa (20,000 lb/in^2)	700 MPa (100,000 lb/in^2)
Melting temperature	115°C (239°F)	135°C (275°F)

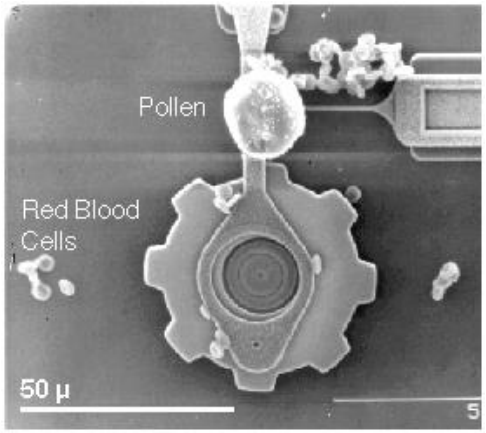
Metals

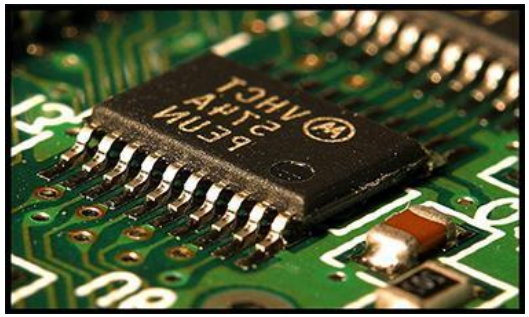


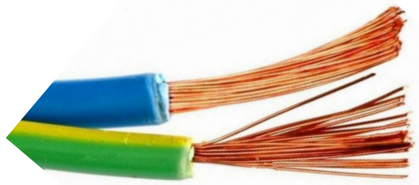
Pure Metal

- Crystalline
- Metallic Bonding

- *High stiffness and strength*
- *Toughness*
- *Good electrical conductivity*
- *Good thermal conductivity*

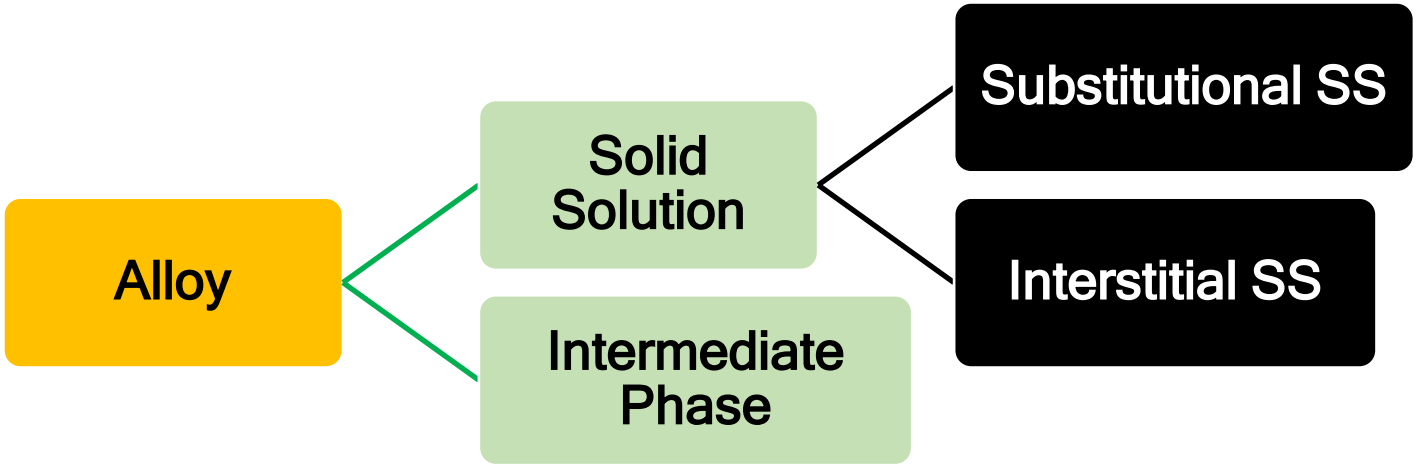






Courtesy: Google Images

Alloys

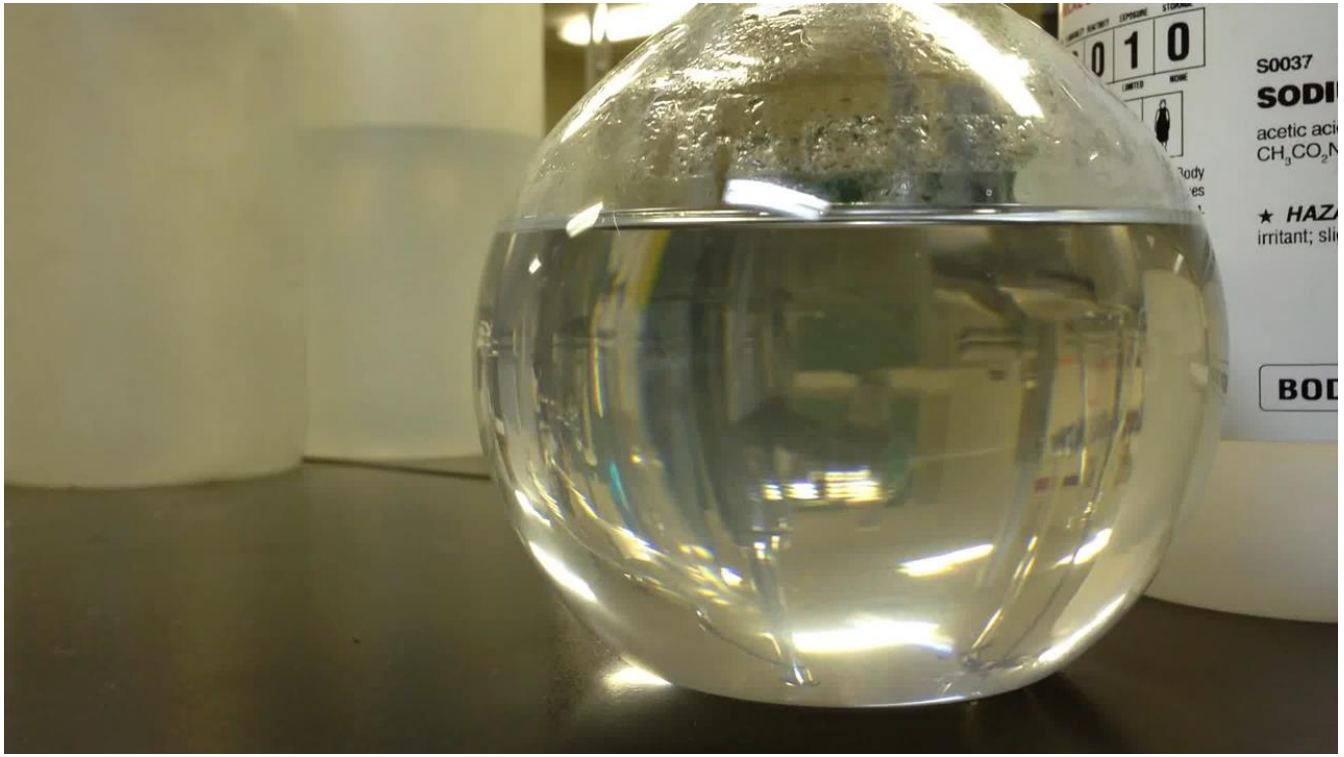


- Composed of two or more elements, at least one of which is metallic
- Solid solution:
  - Base metal + dissolved elements (metal or non metal)
- Phase

Solutions

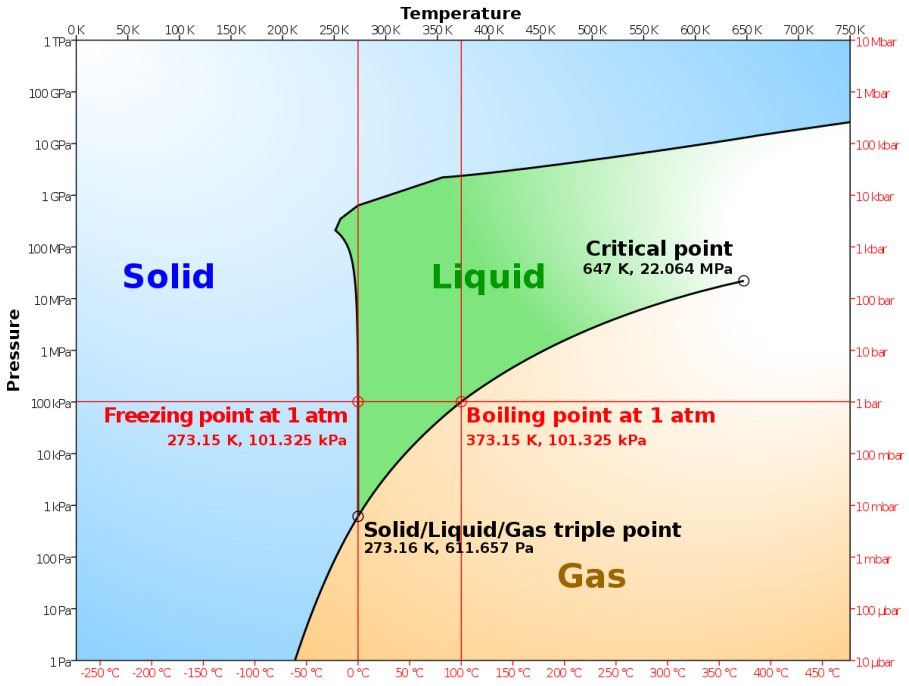
Re-brush

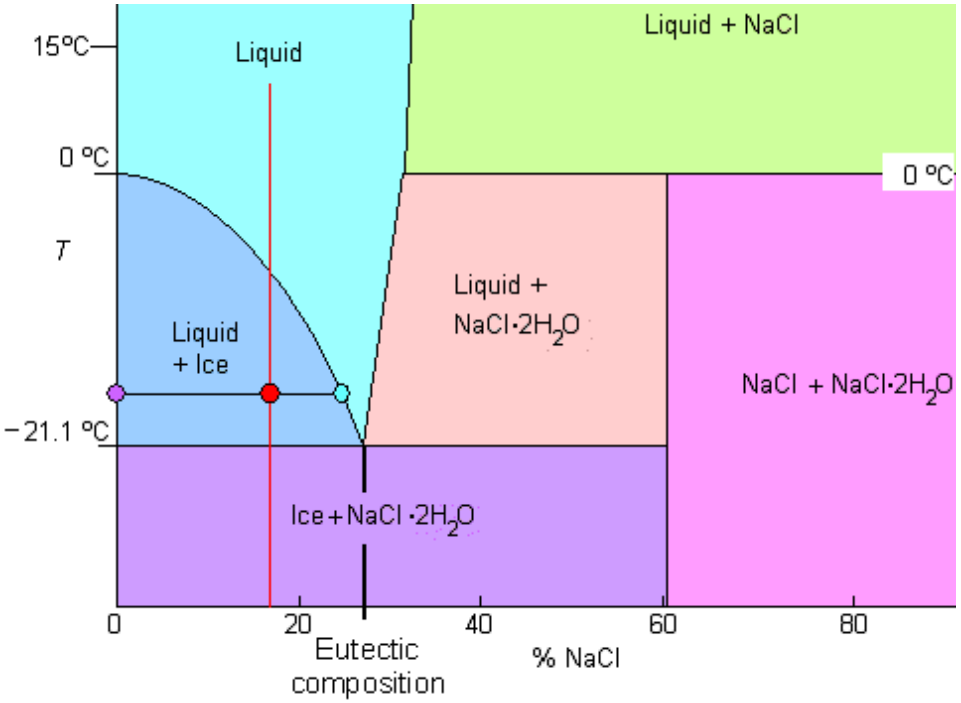
Salt + Water >>> Salt solution
>>> + Salt >>> Saturated salt solution
>>> +Salt >>> SuperSaturated salt solution
>>> +Salt >>> Precipitation Salt + solution



https://www.youtube.com/watch?v=FcxZ9DyOaUk

Phase???





- Phase is a space of thermodynamic system throughout which the physical properties remain uniform. e.g. crystal structure, metallic characteristics, etc.

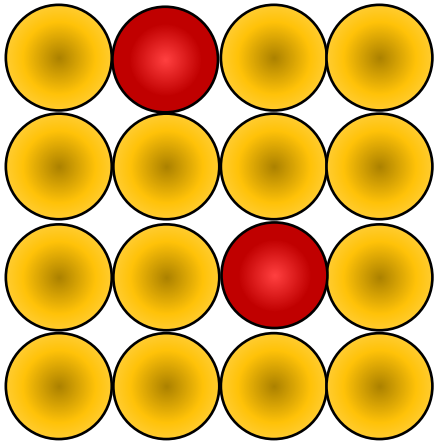
- A simple description is that a phase is a region of material that is chemically uniform, physically distinct, and (often) mechanically separable.

Courtesy: Google Images

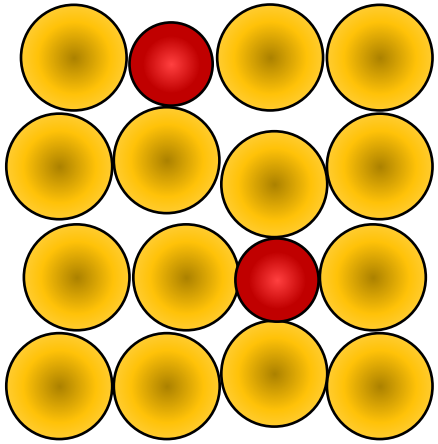
Solid solutions

Substitutional

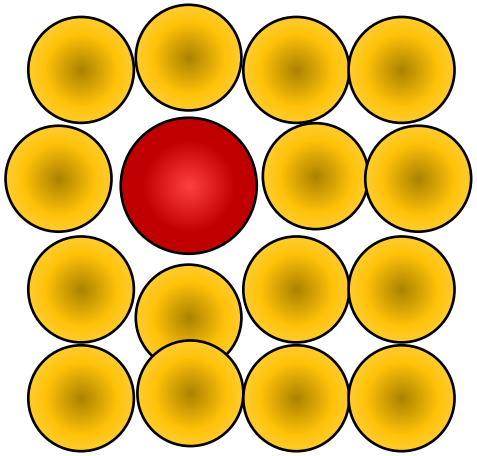
Cu in Ni



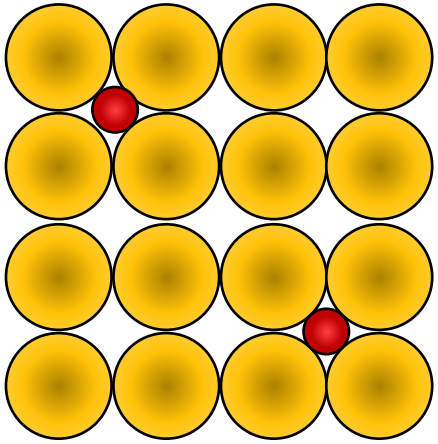
Cu in Ag



Zn in Cu

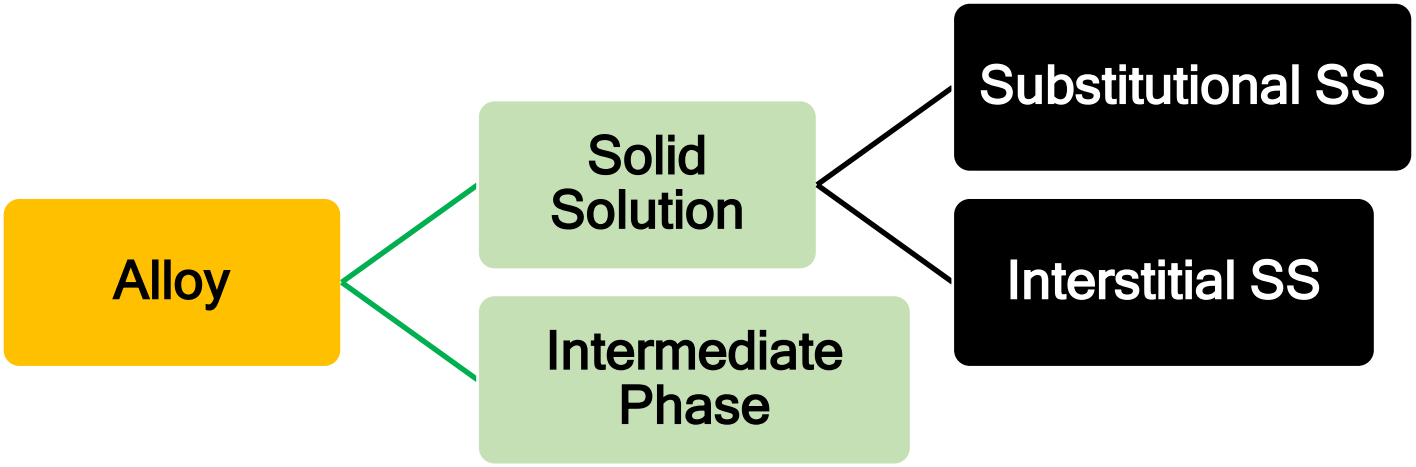


Interstitial



C in Fe

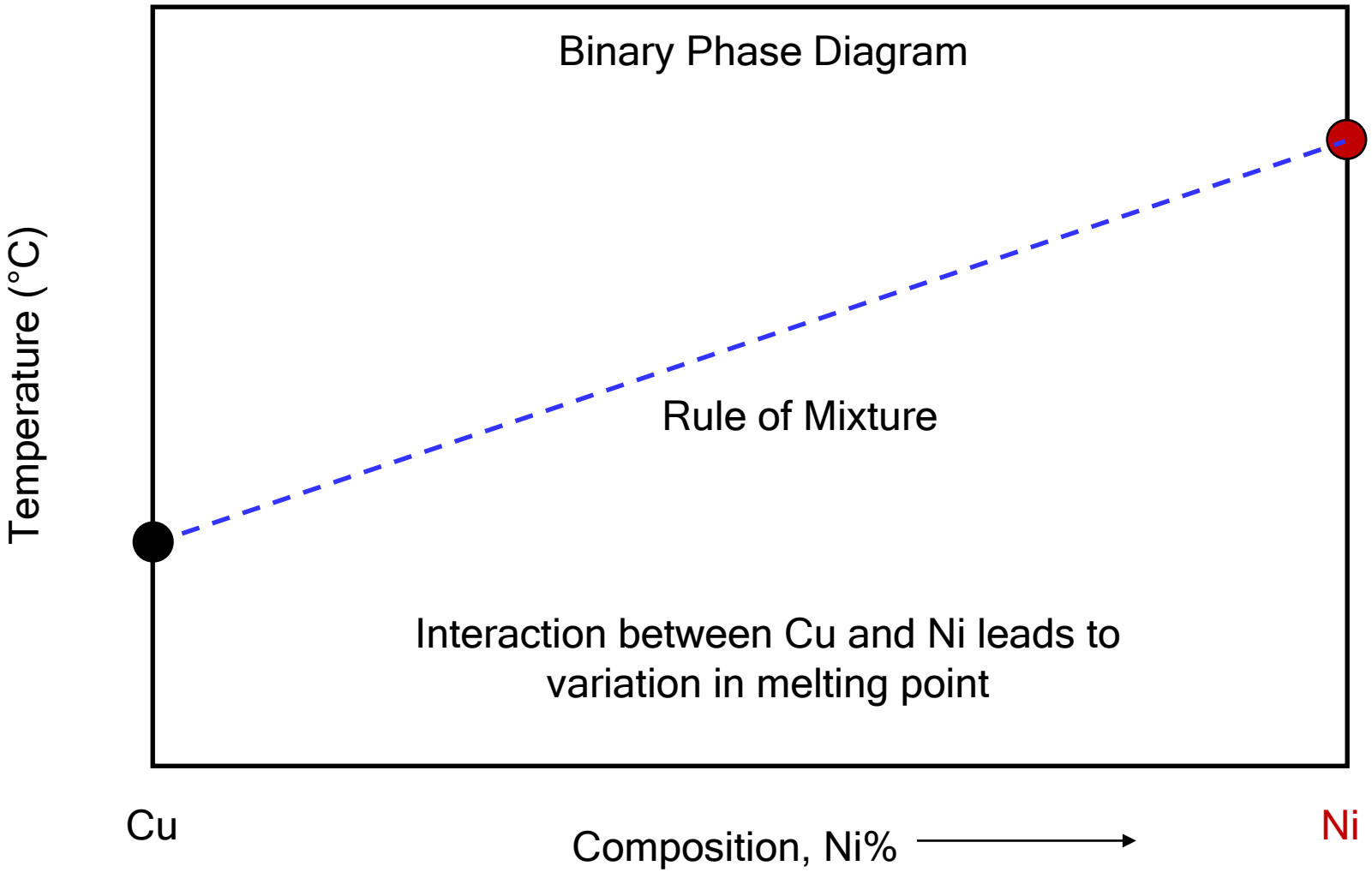
Intermediate phases



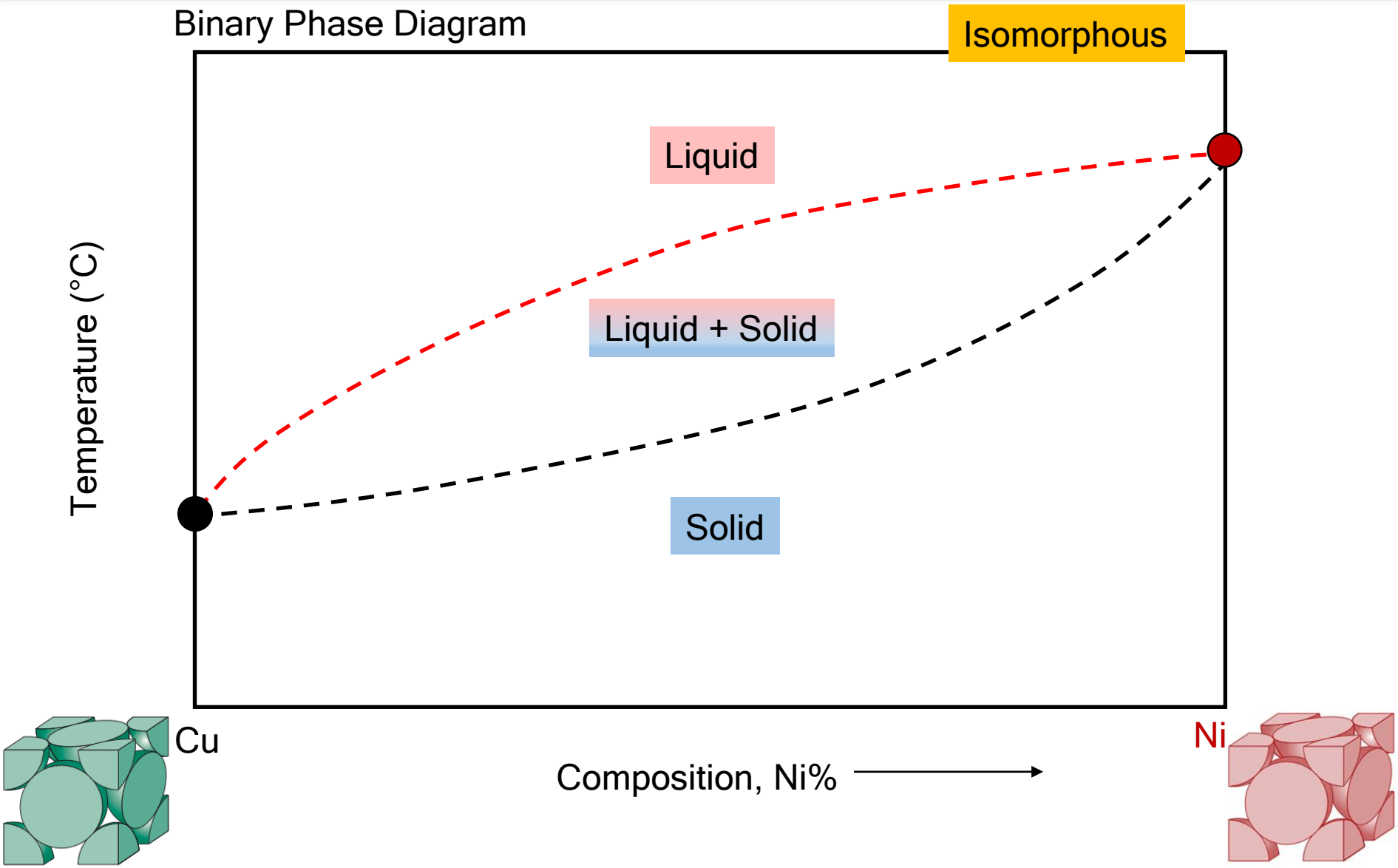
Intermediate phases

- Solid solubility limit (SSL)
- [Dissolving element in alloy] > SSL →Second phase forms
- Metallic compound (metal + non metal), Fe_3C
- Intermetallic (two metals), Mg_2Pb

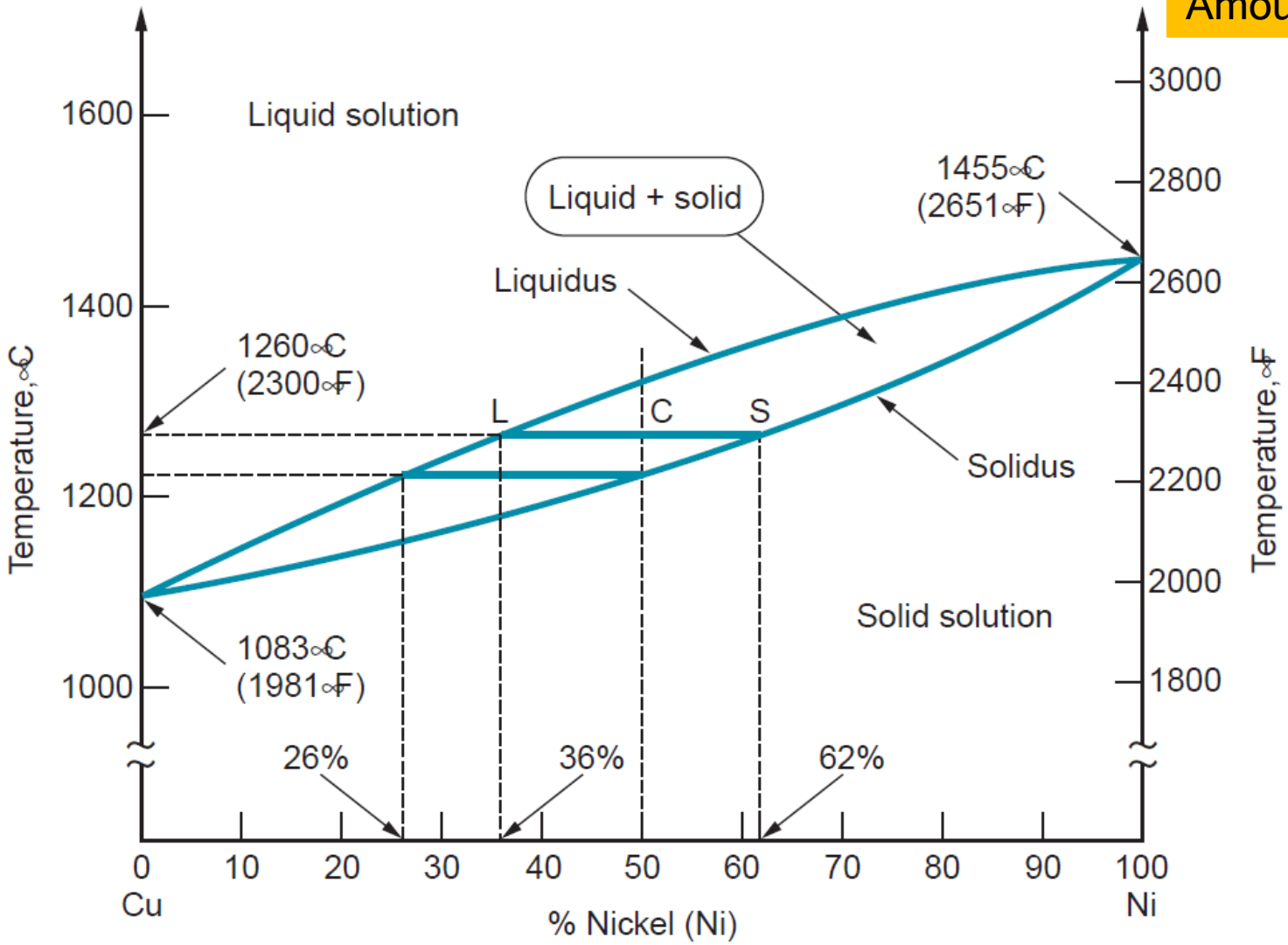
Phase diagram



Cu-Ni phase diagram



Cu-Ni phase diagram



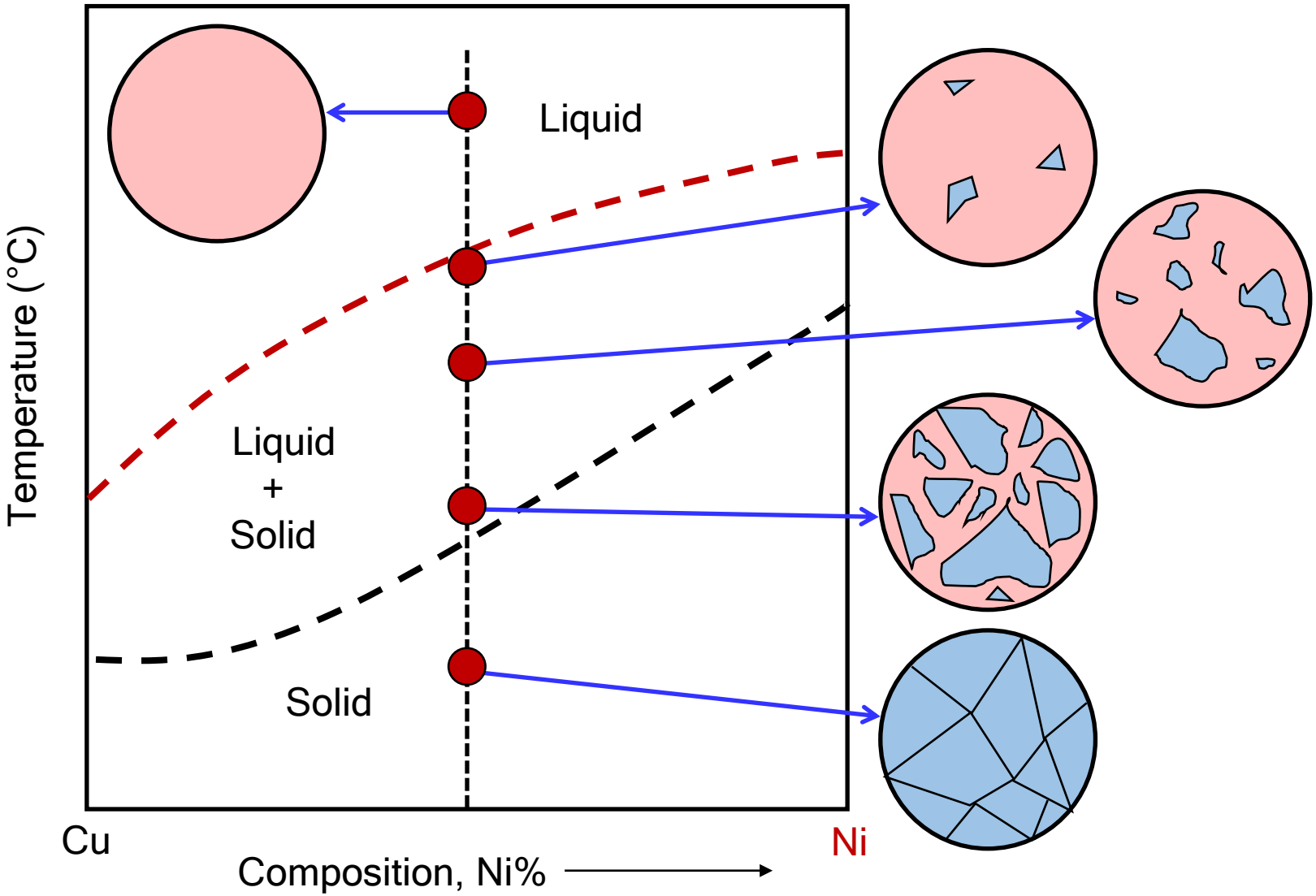
Amount of each phase

$$L = \frac{CS}{CS+CL}$$

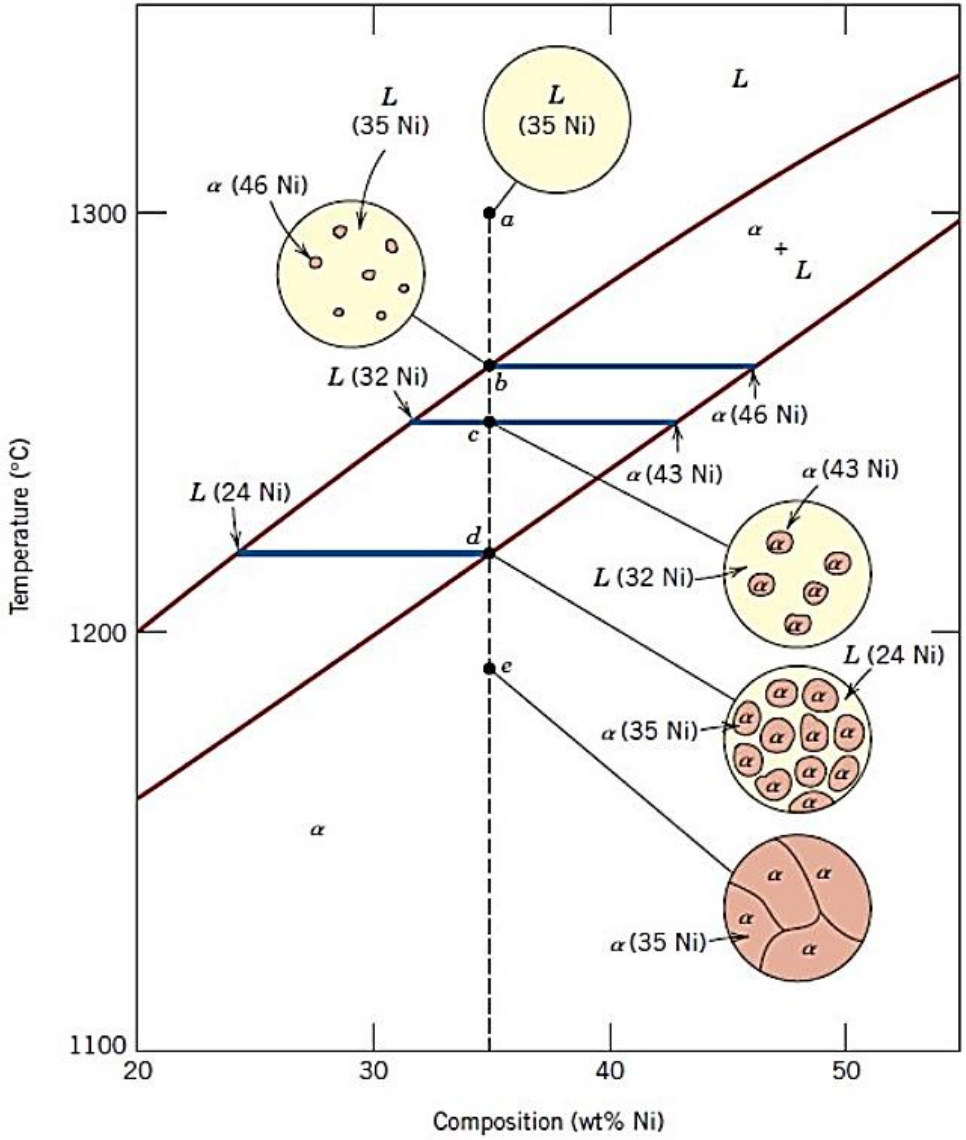
$$S = \frac{LC}{CS+CL}$$

What is the composition of liquid and solid phases for an alloy with 50% Ni at 1260 °C?

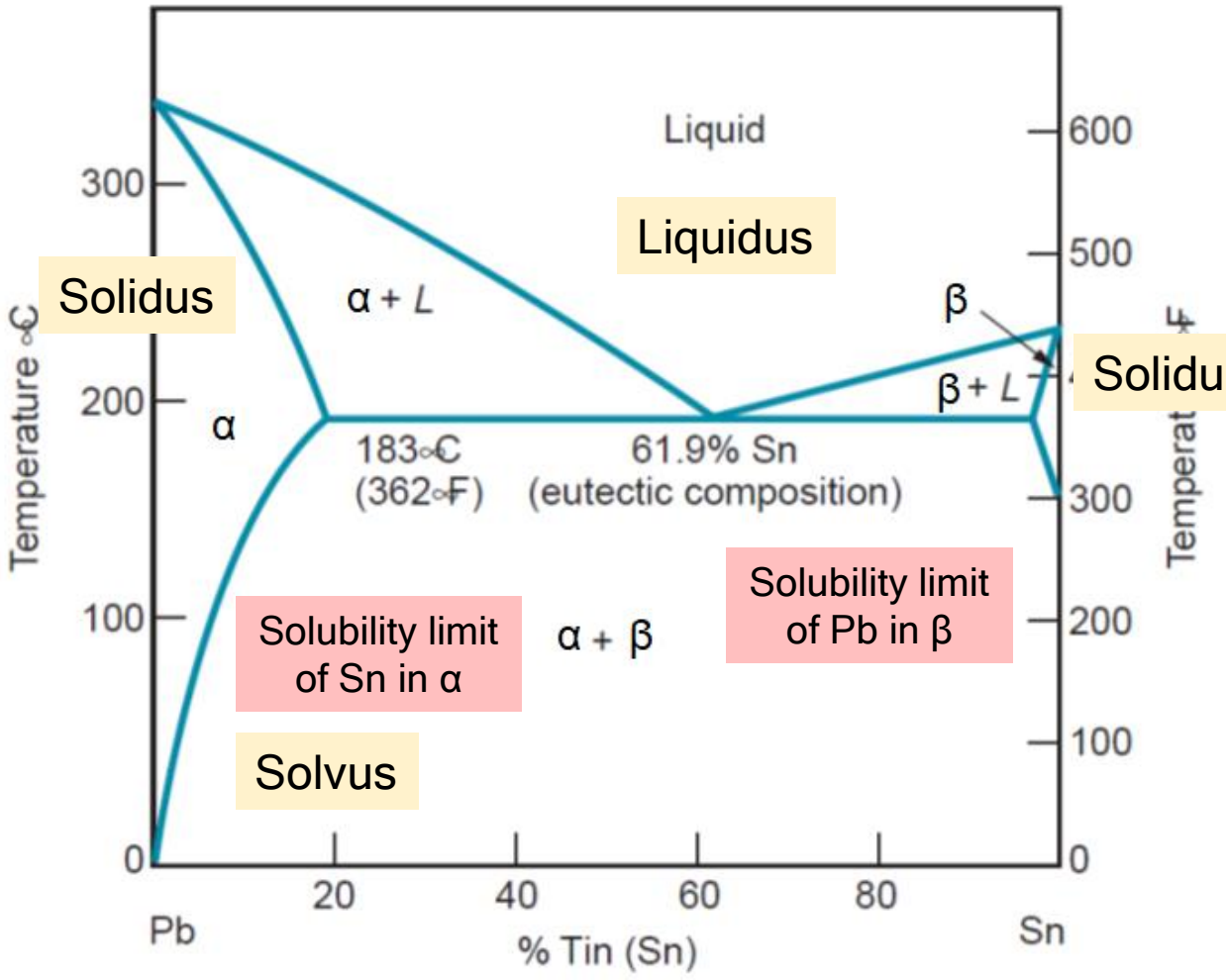
Solidification Process in an isomorphous alloy system



Solidification: Composition



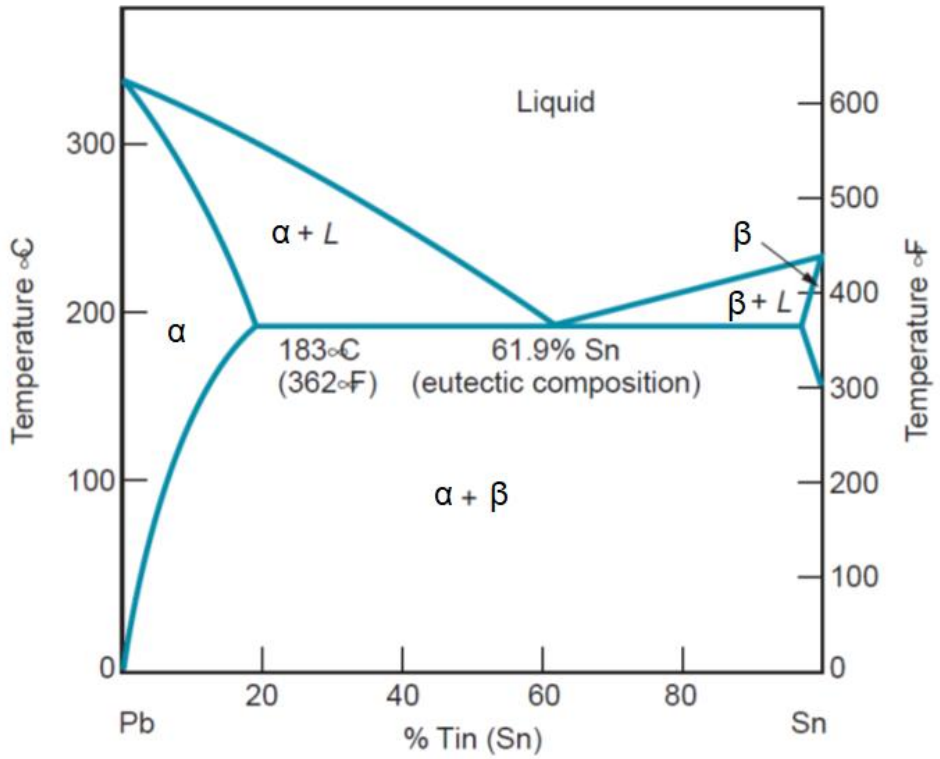
Eutectic Phase Diagram



- ✓ Eutectic point
- ✓ Single phase regions
- ✓ More than one solid phase
- ✓ Multi-phase regions
- ✓ Melting of eutectic

What is the composition of various phases at any given temperature?
What is the amount of phase at that temperature for a given alloy composition?

Eutectic Phase Diagram: Pb-Sn system



- Alpha (α): solid solution of tin in lead
- Beta (β): solid solution of lead in tin
- Characteristics:
  - Presence of two solid phases
  - Alloy melts at lower T
- **Eutectic alloy** is a particular composition in an alloy system for which the solidus and liquidus are at the same T