MLL 100

Introduction to Materials Science and Engineering

Lecture-10 (January 28, 2022)

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What have we learnt in Lecture-9?

- Component
- Phase
- Phase diagram
- Phase equilibrium
- Chemical potential
- Gibb’s phase rule

Gibb's phase rule

- Gives information about the conditions of phase equilibrium in different systems.

$$F = C - P + 2$$

Degree of freedom

No. of components

No. of phases

Variables (*T, P*)

Phases

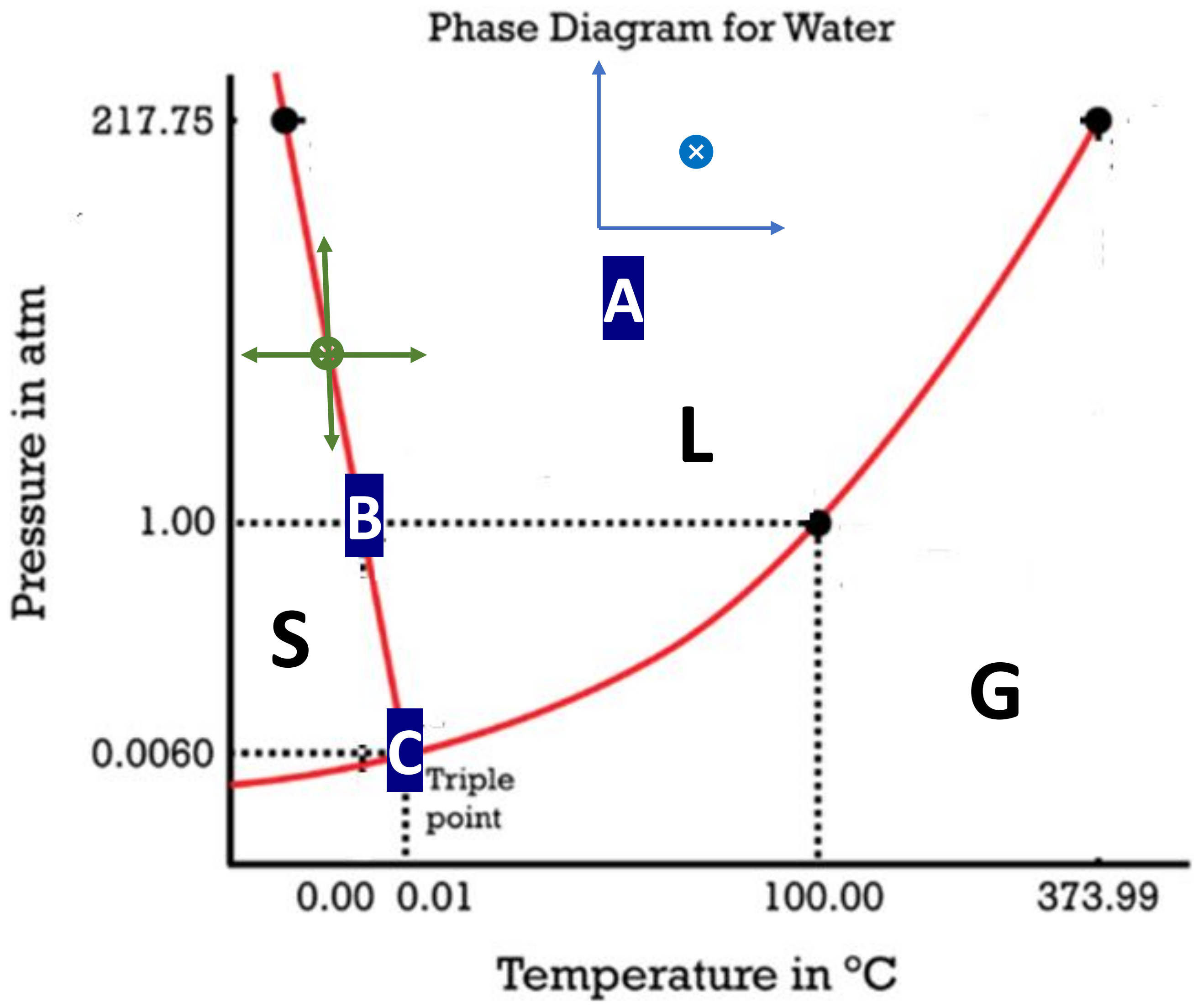
→ Different crystal structure (same component)

→ Different states of matter

→ Same crystal structure; but two different elements/components

Cu, Ni → FCC

Single-component system



A

C = 1

P = 1

F = 1-1+2 = 2

Both T and P can be varied independently, still will be in 'L' phase.

B

C = 1

P = 2

F = 1-2+2 = 1

Either T and P can be varied independently.

C

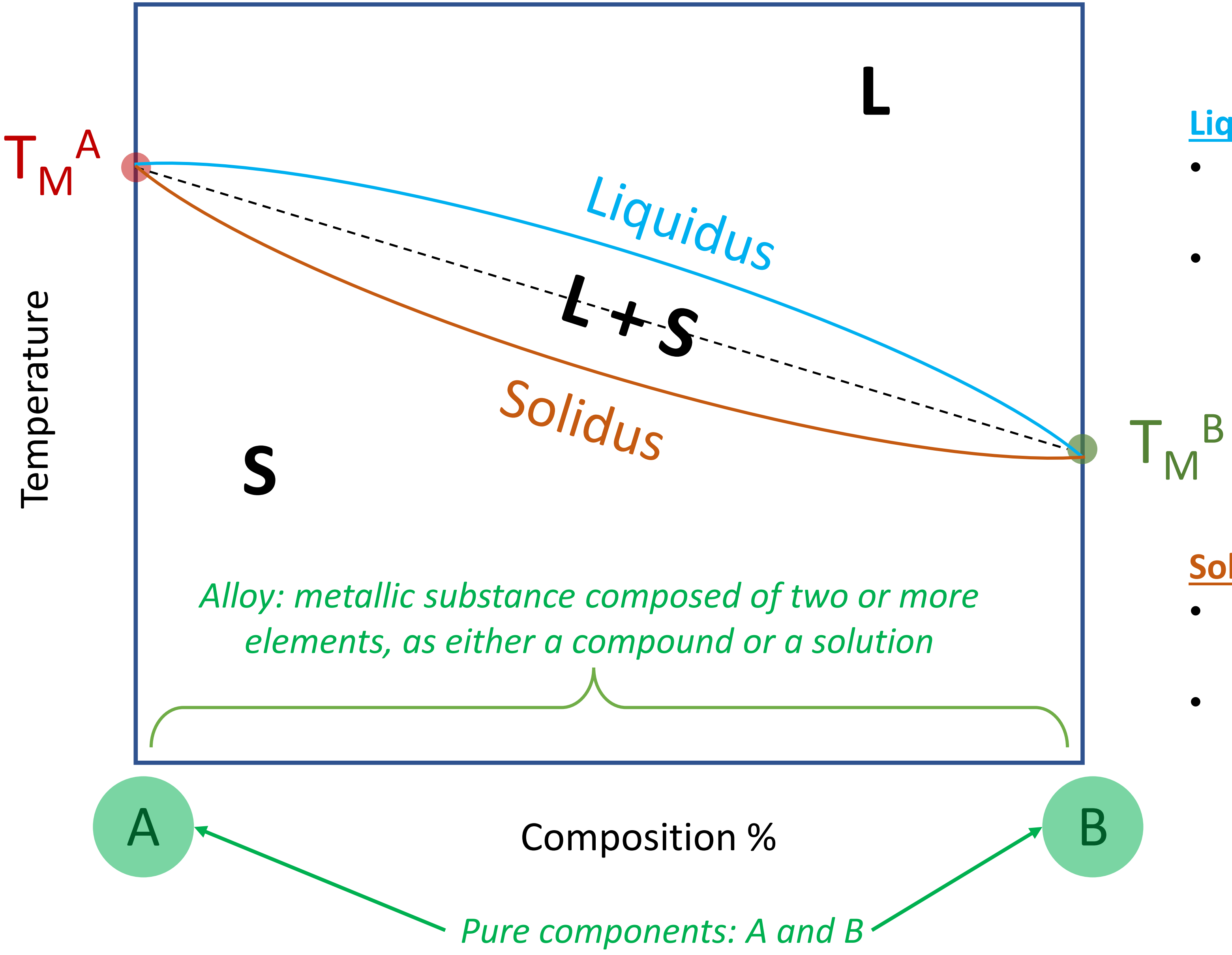
C = 1

P = 3

F = 1-3+2 = 0

Neither T and P can be varied independently.

Binary system *(Pressure is constant)*



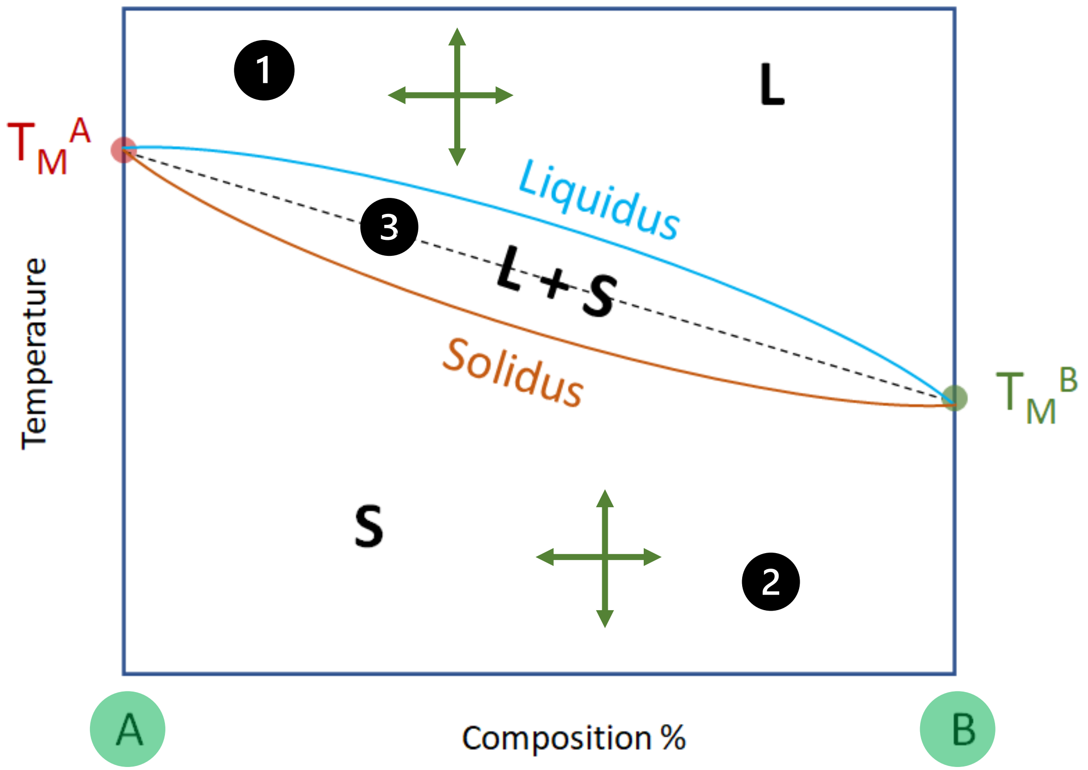
Liquidus:

- Temperature above which the alloy is completely liquid.
- Below Liquidus, solidification starts.

Solidus:

- Temperature below which the alloy is completely solid.
- Above solidus, liquefaction starts.

Condensed Gibb's phase rule *(Pressure is constant)*



$$F = C - P + 1$$

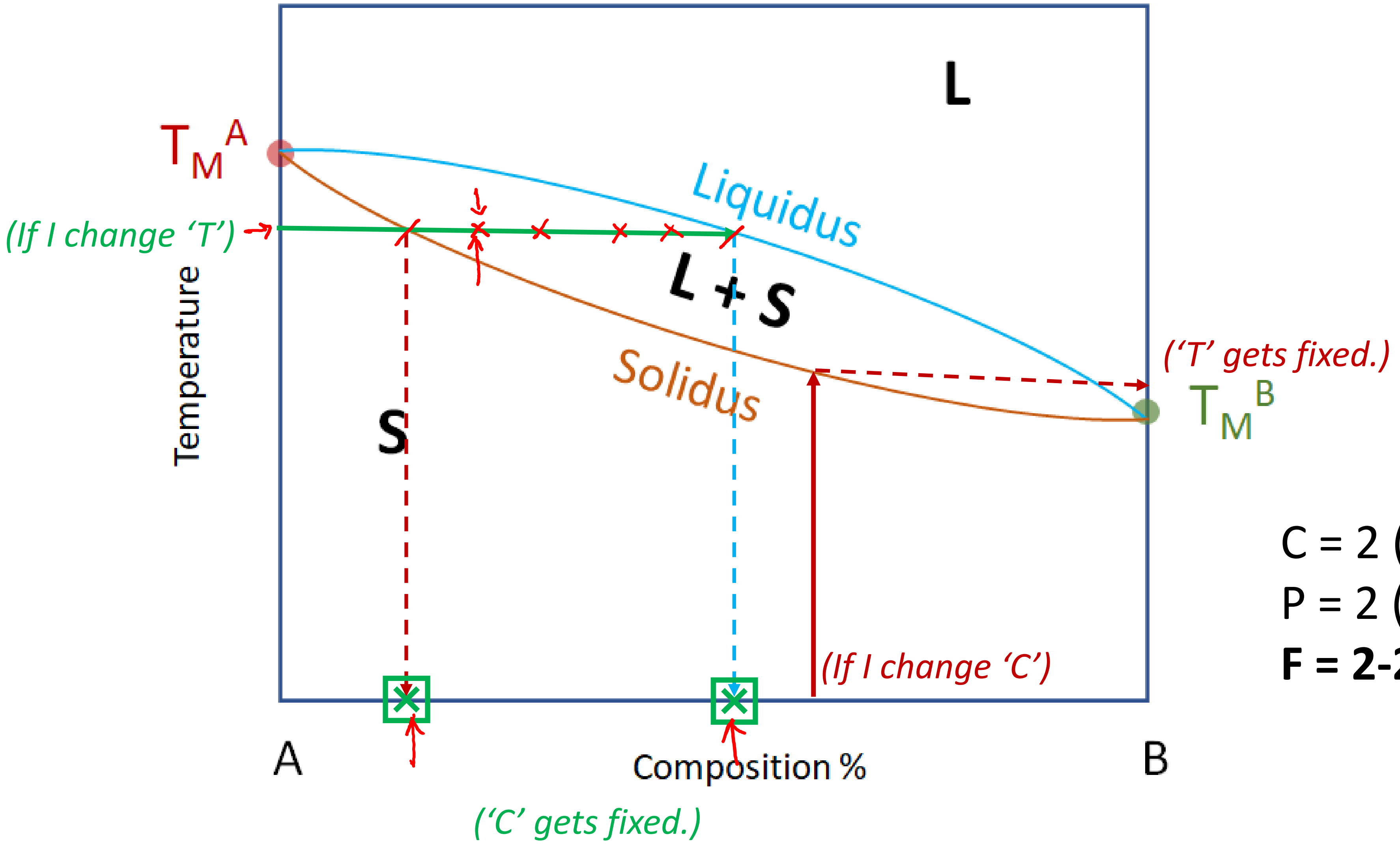
- Pressure is constant.
- '1' stands for the state variable: Temperature.

1. C = 2 (A and B)
P = 1 (Liquid)
F = 2-1+1 = 2
   - Both T and C can be varied independently, still will be in 'L' phase.

2. C = 2 (A and B)
P = 1 (Solid)
F = 2-1+1 = 2
   - Both T and C can be varied independently, still will be in 'S' phase.

3. C = 2 (A and B)
P = 2 (Liquid + Solid)
F = 2-2+1 = 1
   - Either T or C can be varied independently, only then 'L+S' two-phase will be in equilibrium.

❸ Anywhere within the two-phase region (L + S)



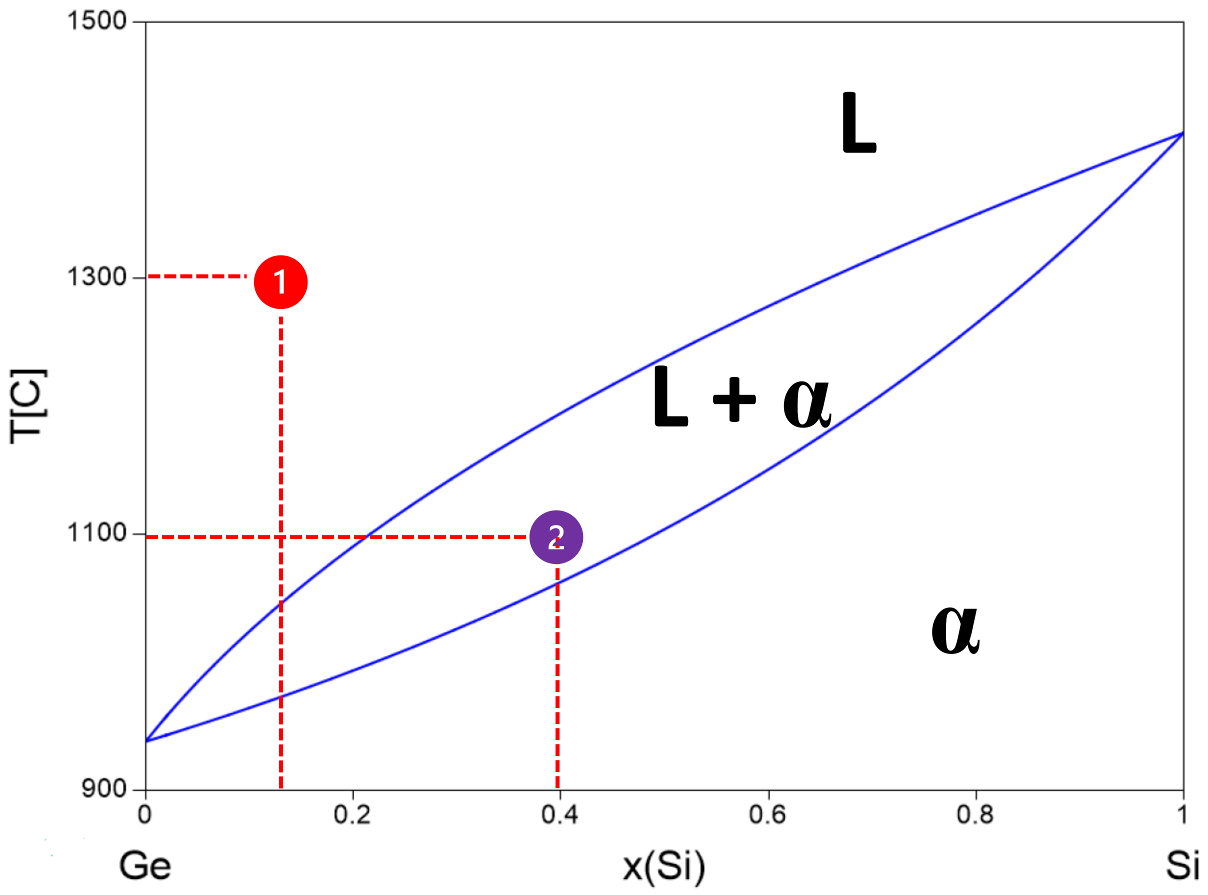
C = 2 (A and B)

P = 2 (Liquid + Solid)

F = 2-2+1 = 1

- Either T or C can be varied independently, only then 'L+S' two-phase will be in equilibrium.

Isomorphous phase diagram



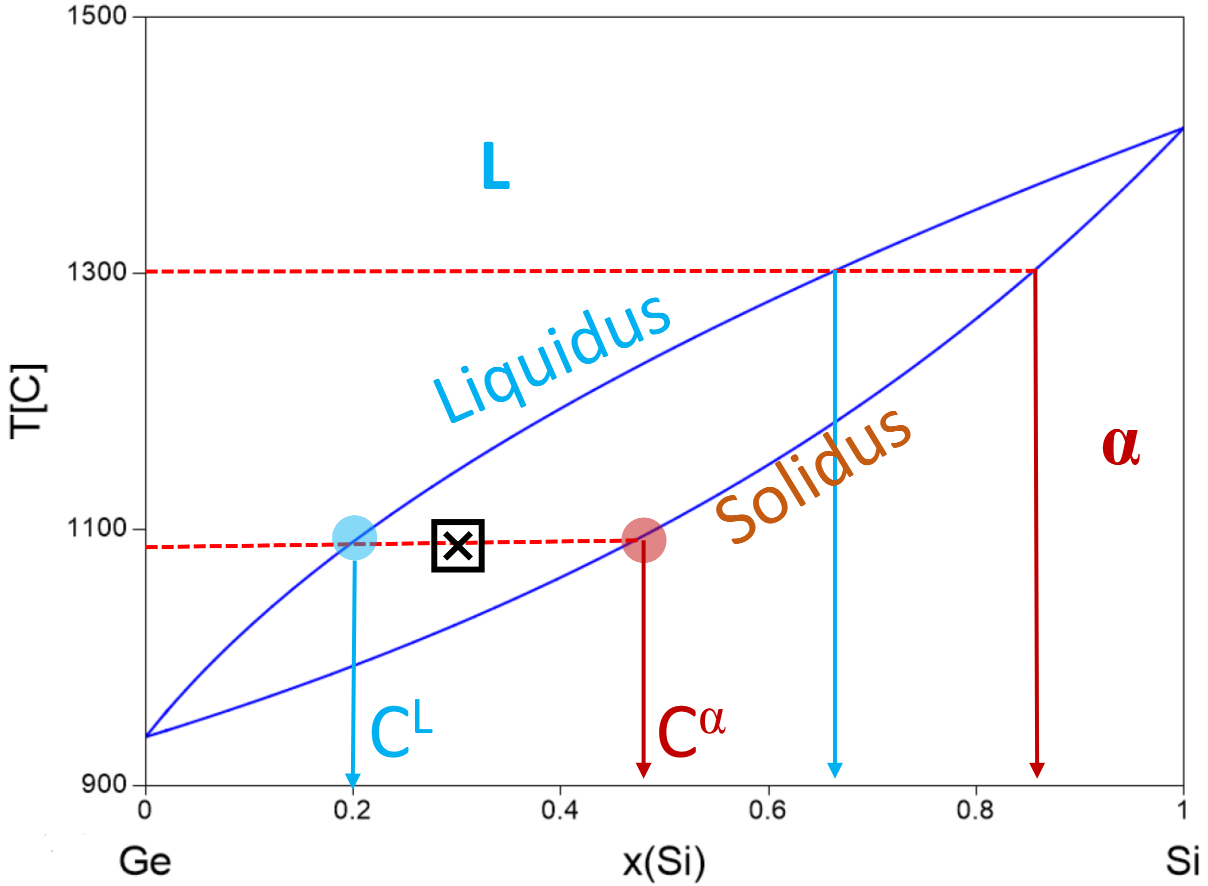
- ❑ Which phases are in equilibrium?

(Temperature and Composition)

1 Phase: Liquid (L)

2 Phase: Liquid (L) + α

Tie-line

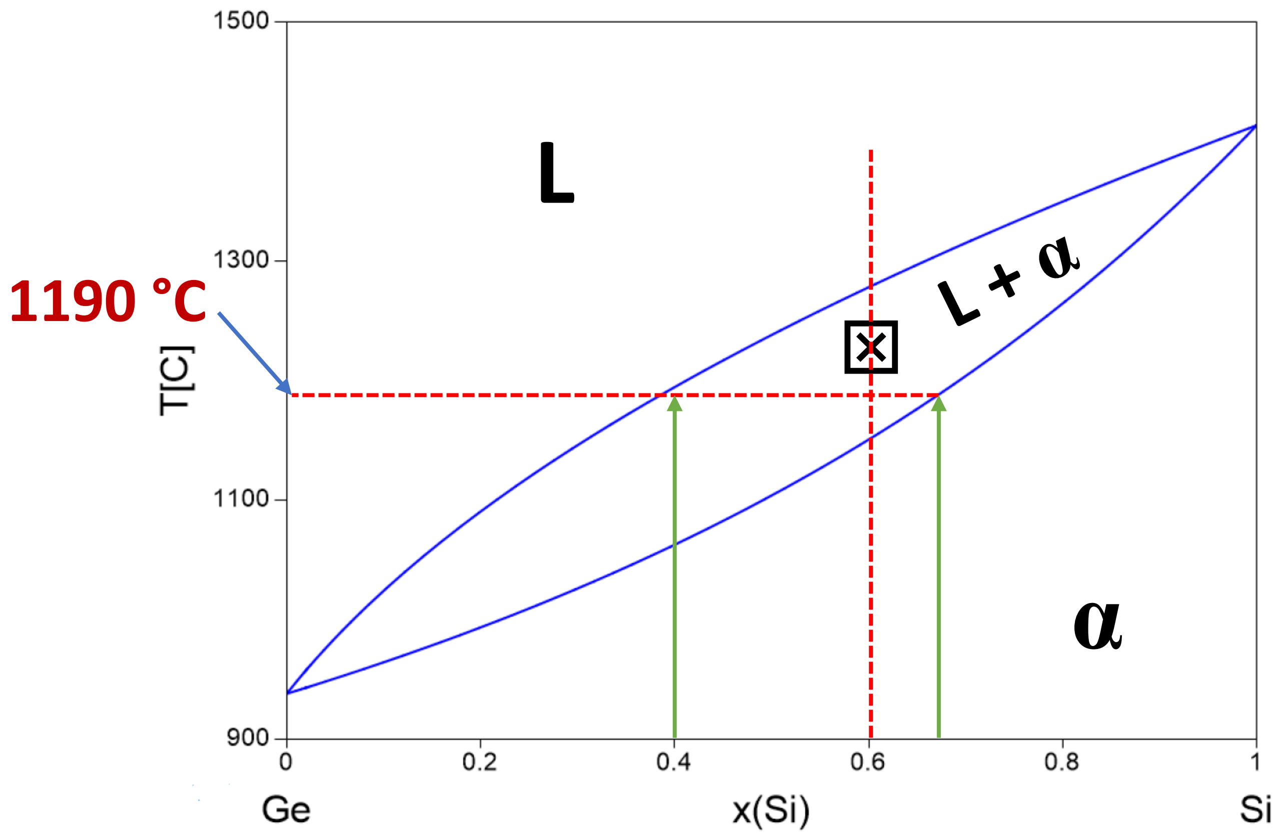


- What are the composition of phases in equilibrium?

C^L : Composition of liquid phase

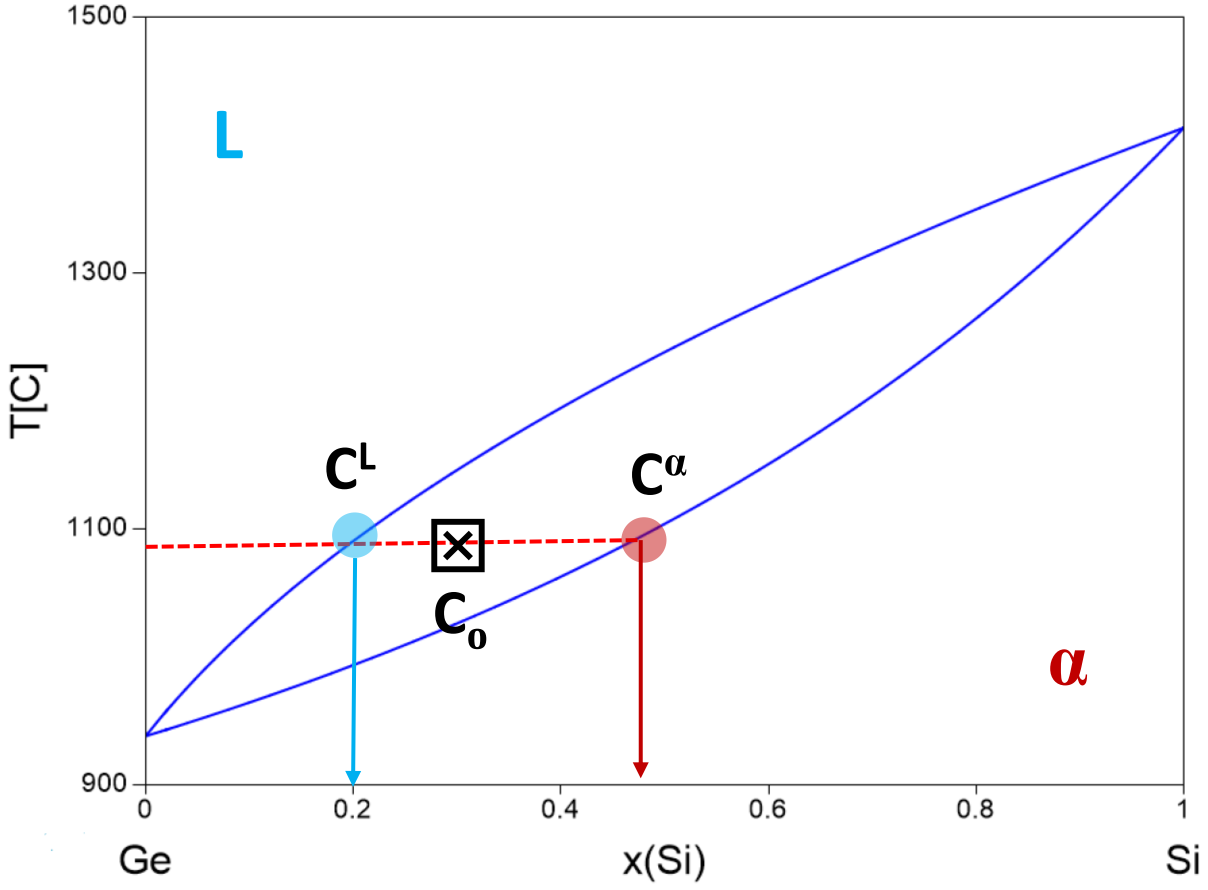
C^α : Composition of α phase

An alloy with an average composition, C_o = 0.6 % Si has two phases in equilibrium. The composition of the phases, L and α are 0.40 and 0.67 % Si respectively. At what temperature is such an alloy stable?



Lever rule

C_o : average composition of alloy



- In what fraction are the phases present?

$$\frac{f_L}{f_\alpha} = ?$$

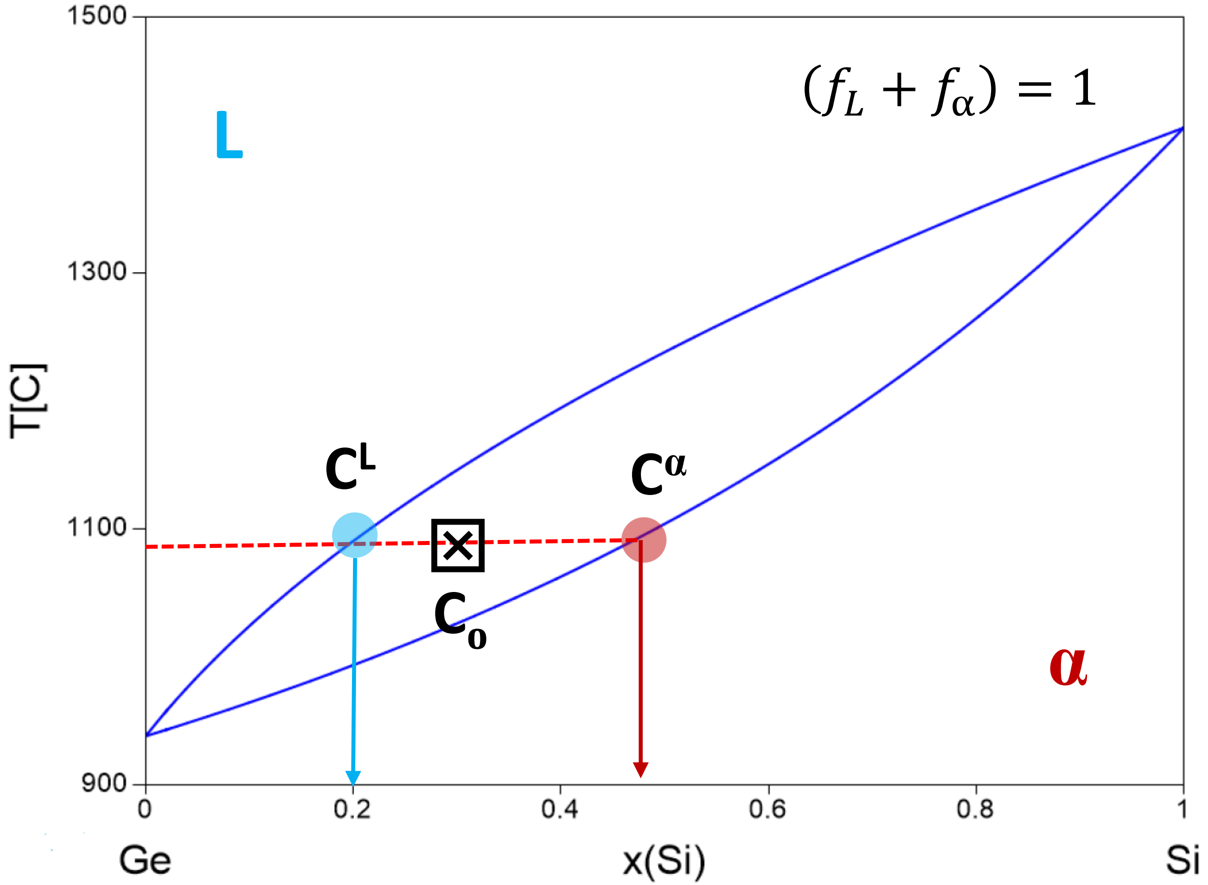
$$f_L . C^L + f_\alpha . C^\alpha = (f_L + f_\alpha) . C_o$$

$$\frac{f_L}{f_\alpha} . C^L + 1 . C^\alpha = \left(\frac{f_L}{f_\alpha} + 1\right) . C_o$$

$$\frac{f_L}{f_\alpha} = \frac{(C_o - C^\alpha)}{(C^L - C_o)}$$

Lever rule

C_o : average composition of alloy



$$f_\alpha = \frac{(C^L - C_o)}{(C^L - C^\alpha)} \qquad f_L = \frac{(C_o - C^\alpha)}{(C^L - C^\alpha)}$$

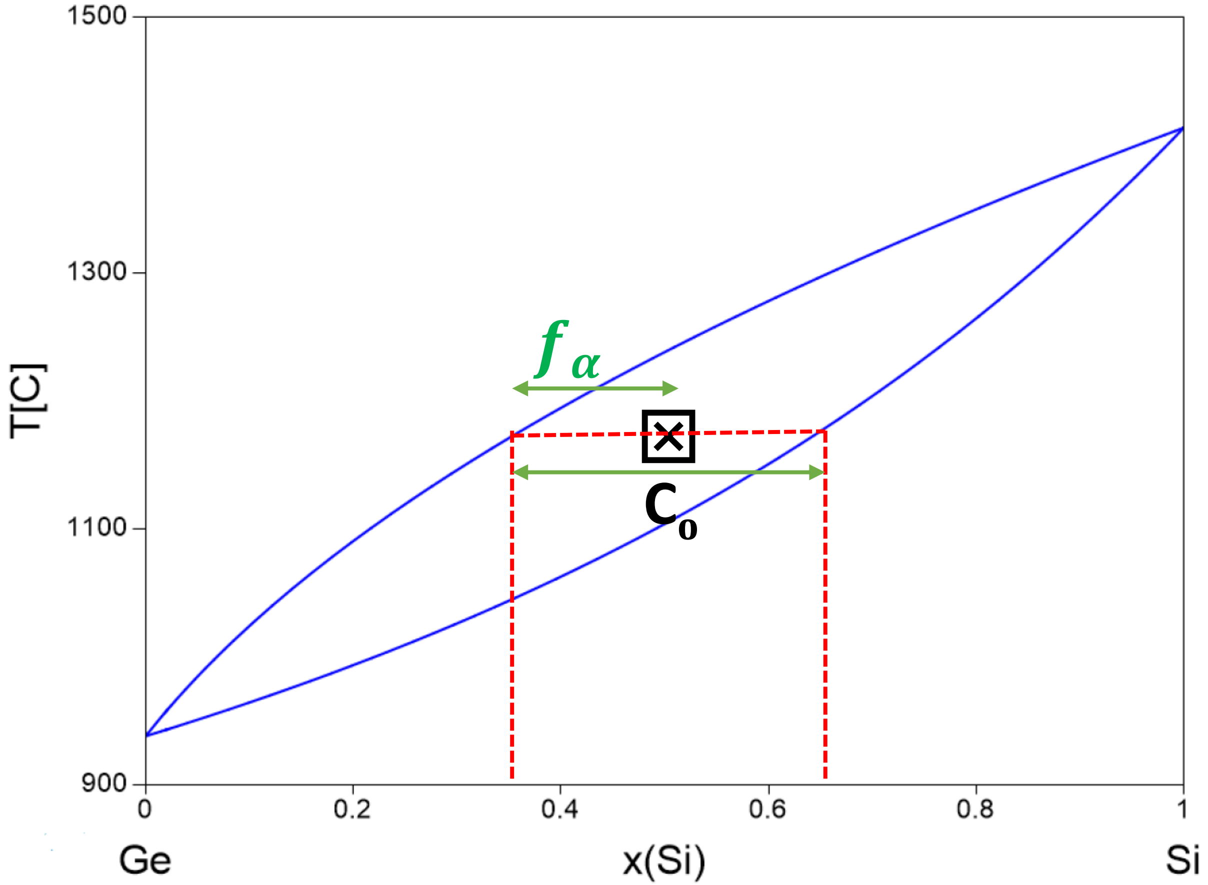
- In what fraction are the phases present?

$$\frac{f_L}{f_\alpha} = \frac{(C_o - C^\alpha)}{(C^L - C_o)}$$

$$1 + \frac{f_L}{f_\alpha} = 1 + \frac{(C_o - C^\alpha)}{(C^L - C_o)}$$

$$\frac{f_\alpha + f_L}{f_\alpha} = \frac{(C^L - C_o) + (C_o - C^\alpha)}{(C^L - C_o)}$$

$$\frac{1}{f_\alpha} = \frac{(C^L) - (C^\alpha)}{(C^L - C_o)}$$



$C^L = 0.38$ $C^\alpha = 0.63$

$$f_\alpha = \frac{(C^L - C_o)}{(C^L - C^\alpha)} = \frac{(0.38 - 0.50)}{(0.38 - 0.63)} = 0.48$$

$$f_L = \frac{(C_o - C^\alpha)}{(C^L - C^\alpha)} = \frac{(0.50 - 0.63)}{(0.38 - 0.63)} = 0.52$$