

Binary isomorphous phase diagram

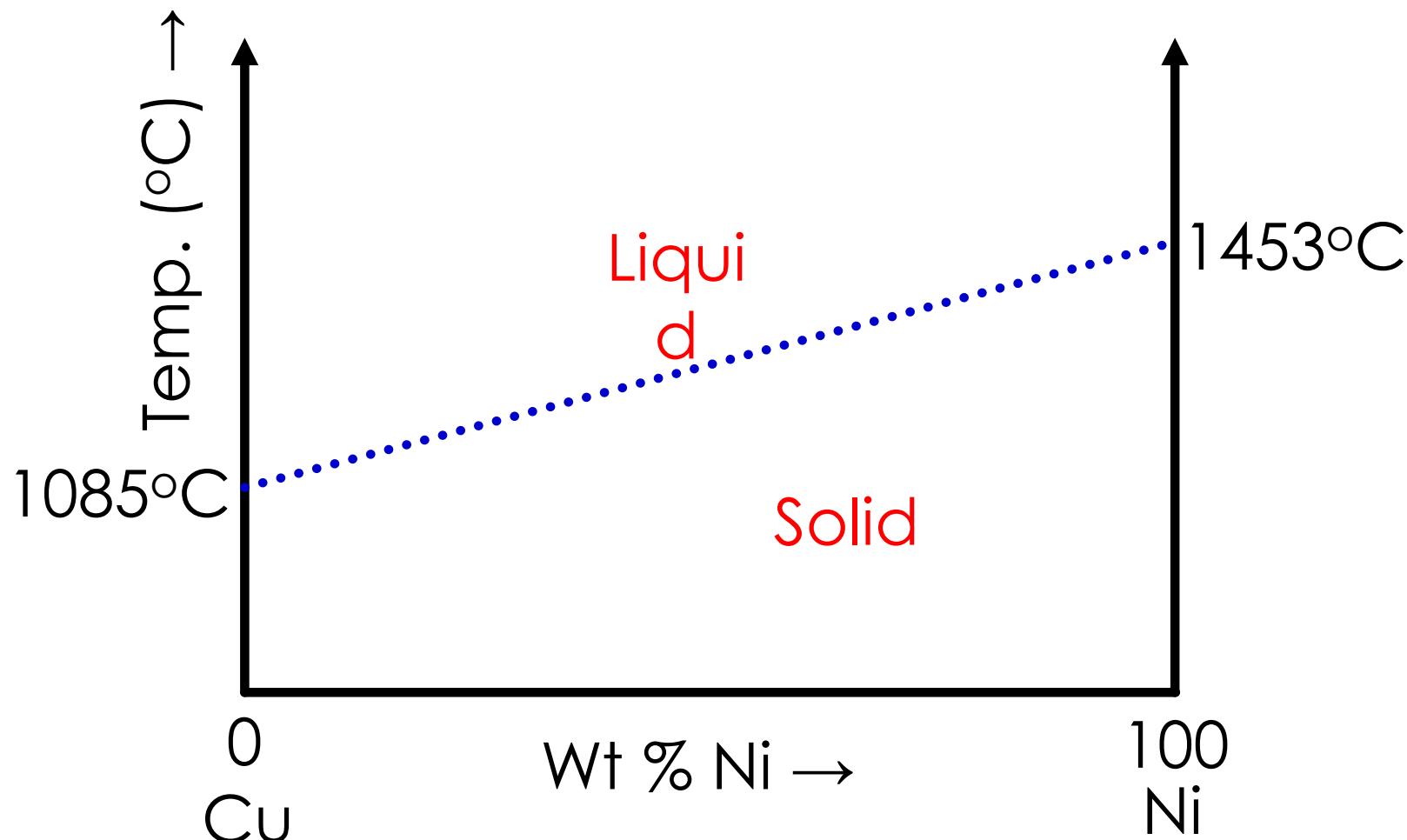
Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Isomorphous Binary Phase Diagram

- Two component system
- Complete solubility in liquid as well as in solid
- Also known as solid solution systems

Expect T_m of solution to lie in between T_m of two pure components



For a pure component, complete melting occurs before T_m increases (sharp phase transition)

But for multicomponent systems, there is usually a coexistence of liquid and solid.

Criteria for formation of Solid Solutions

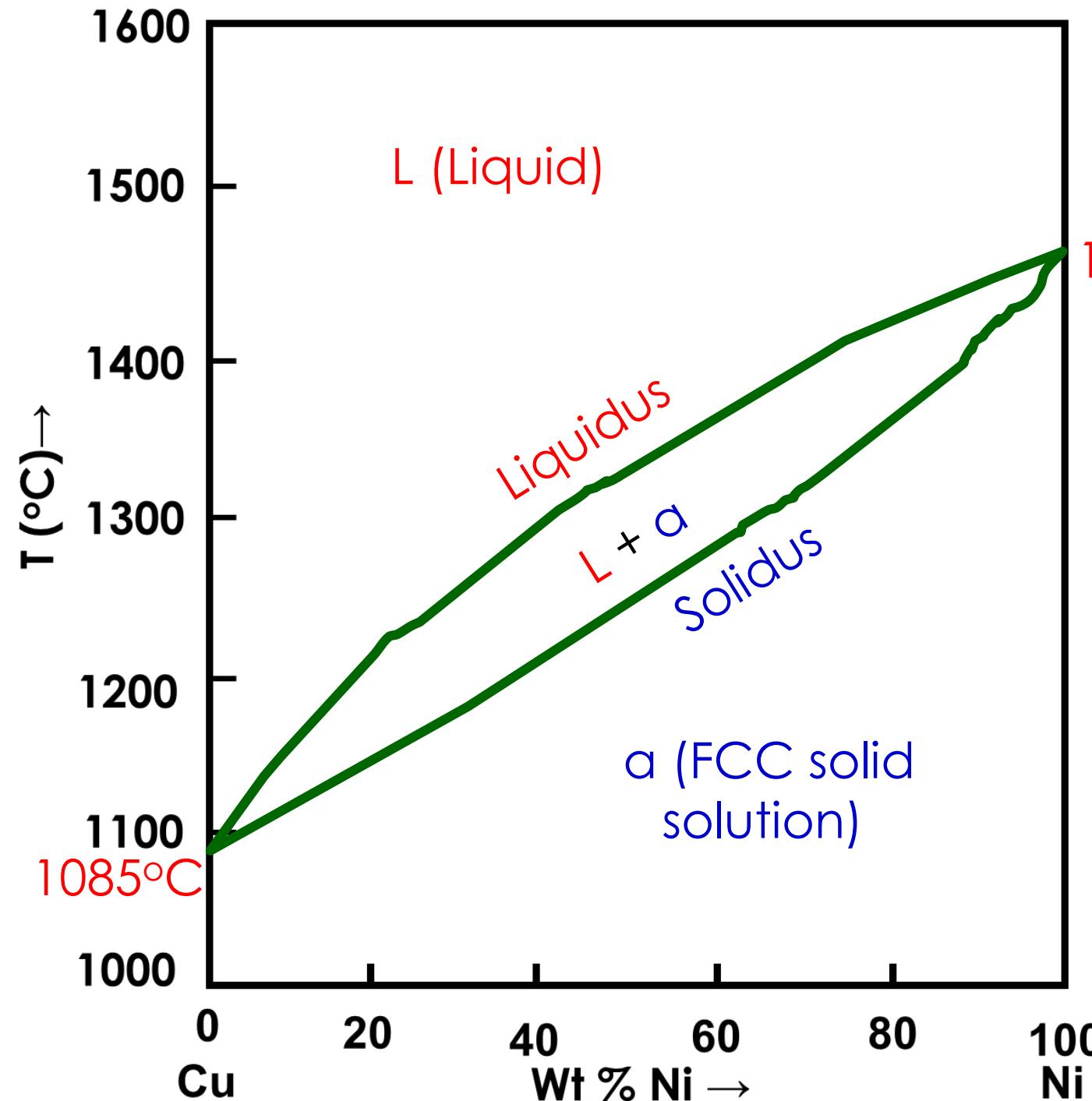
W. Hume-Rothery rules

- Both elements/compound should have the same crystal structure
- Atomic size difference less than 15% (atomic/ionic radii similar)
- Less difference in electronegativity values
- Same valency

Ni and Cu are totally soluble in one another for all proportions.

	Crystal Structure	electroneg	r (nm)
Ni	FCC	1.9	0.1246
Cu	FCC	1.8	0.1278

Isomorphous Binary Phase Diagram



What can we learn from this phase diagram?

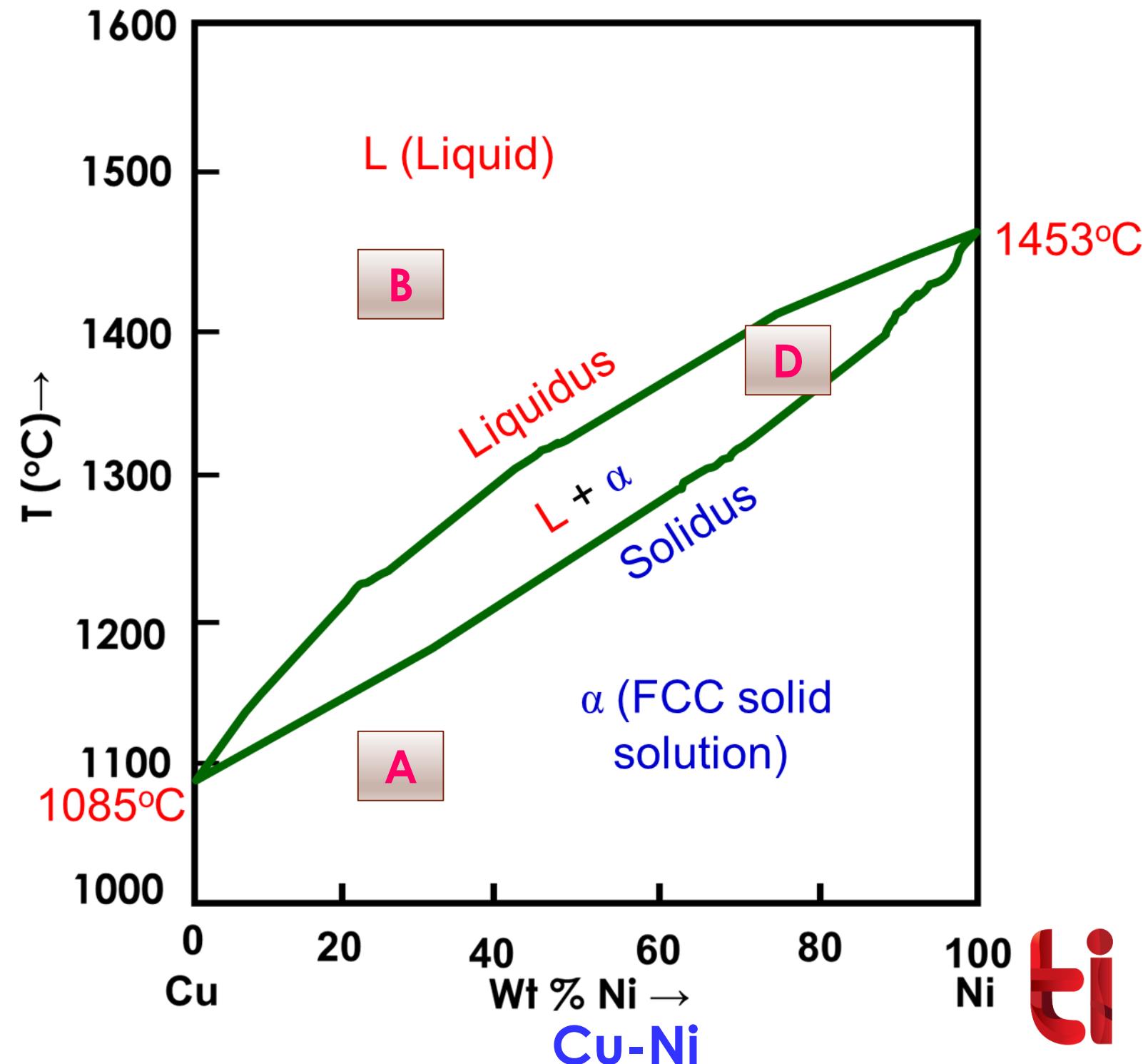
1. Phase(s) present
2. Composition of those phases
3. Amount of the phases

Solidus - Temperature where alloy is completely **solid**. Above this line, liquefaction begins.

Liquidus - Temperature where alloy is completely **liquid**. Below this line, solidification begins.

Effect of Temperature & Composition (C_o)

- Changing T can change # of phases: path A to B.
- Changing C_o can change # of phases: path B to D.

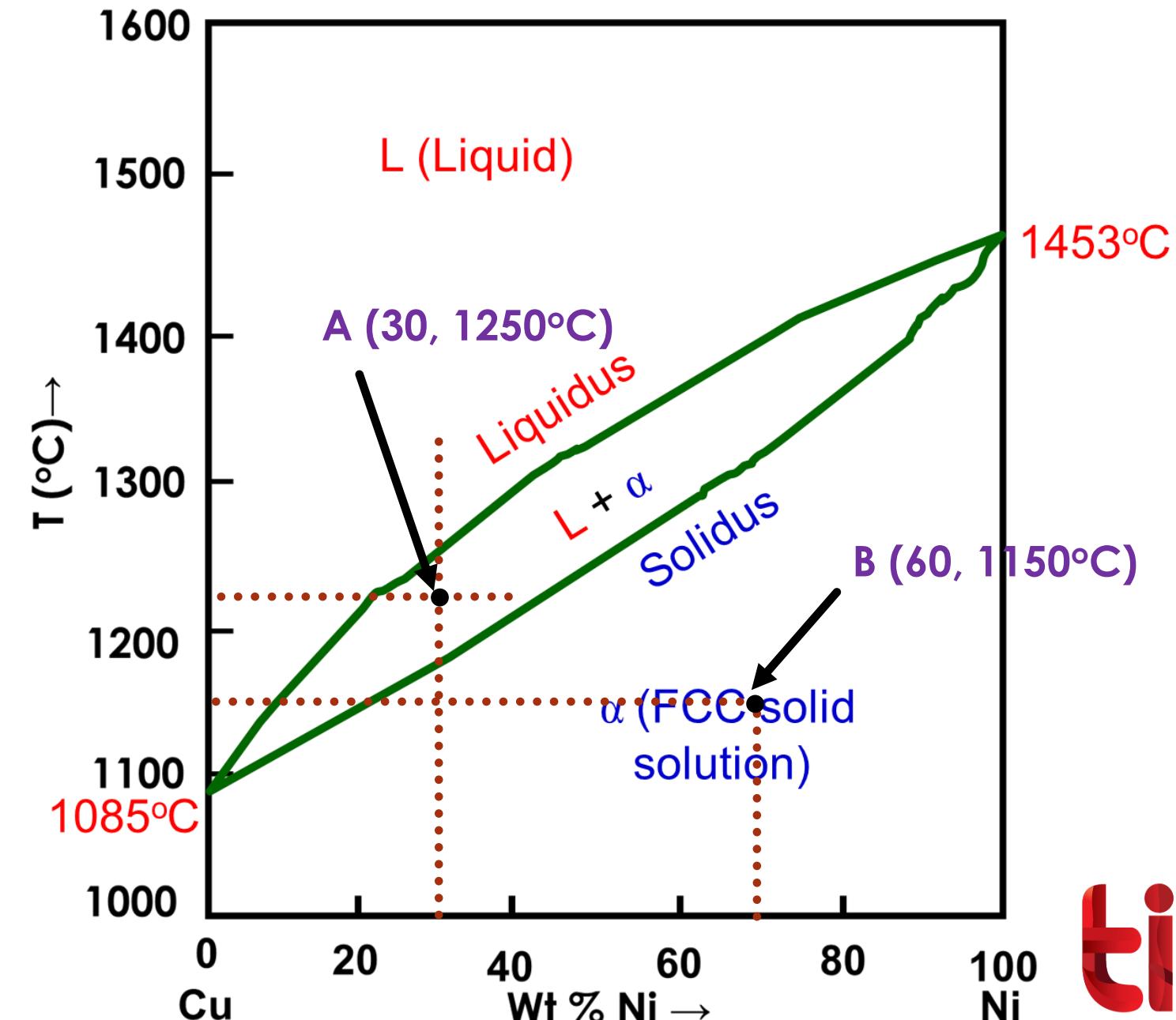


Determination of phase(s) present

- Rule 1: If we know T and Co, then we know:
-how many phases and which phases are present.

Examples

- At Temperature 1225°C and $C_o = 30$ wt. % Ni, no of phases present: L + a. (point A in phase diagram).
- At Temperature 1150°C and $C_o = 60$ wt. % Ni, no of phases present: a. (point B in phase diagram).



Composition of phases

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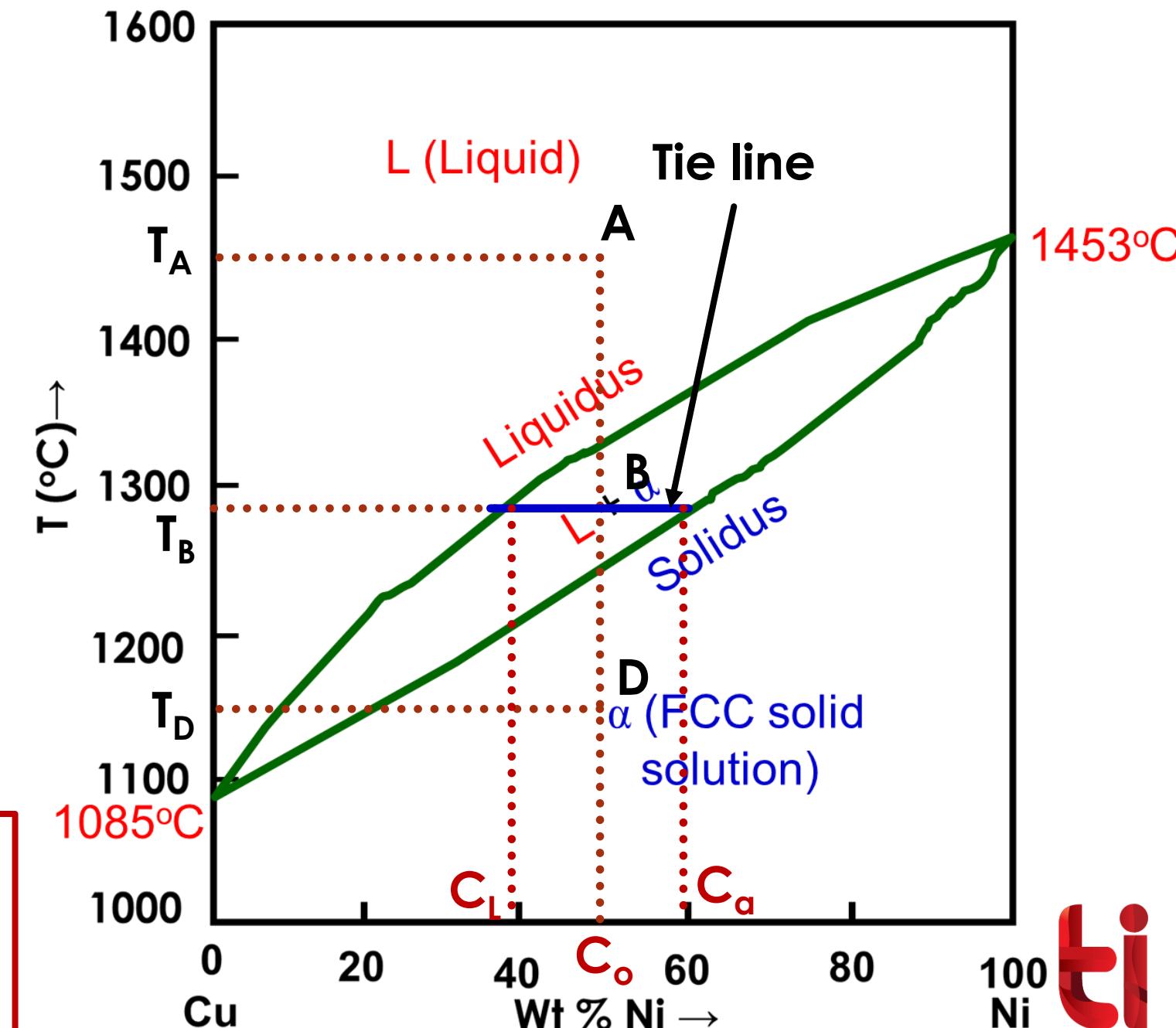
Rule 2: If we know T and Co, then we know:-**the composition** of each phase.

Example

Alloy composition (C_o)= Cu 50 wt. % Ni

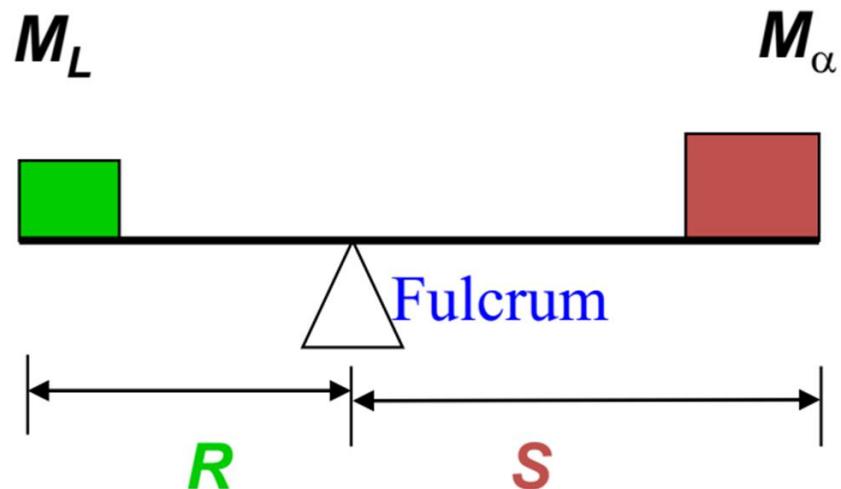
1. At temperature $T_A = 1450^\circ\text{C}$, only liquid phase is present and $C_L = C_o (= 50 \text{ wt.\% Ni})$.
 2. At temperature $T_B = 1275^\circ\text{C}$, Both a and L present, $C_L = 40 \text{ wt. \% Ni}$ and $C_a = 60 \text{ wt. \% Ni}$. Use tie line to identify these composition.
 3. At temperature $T_D = 1190^\circ\text{C}$, only solid (a) present $C_a = C_o (= 50 \text{ wt. \% Ni})$

A tie line is constructed across the two-phase region at the temperature of the alloy



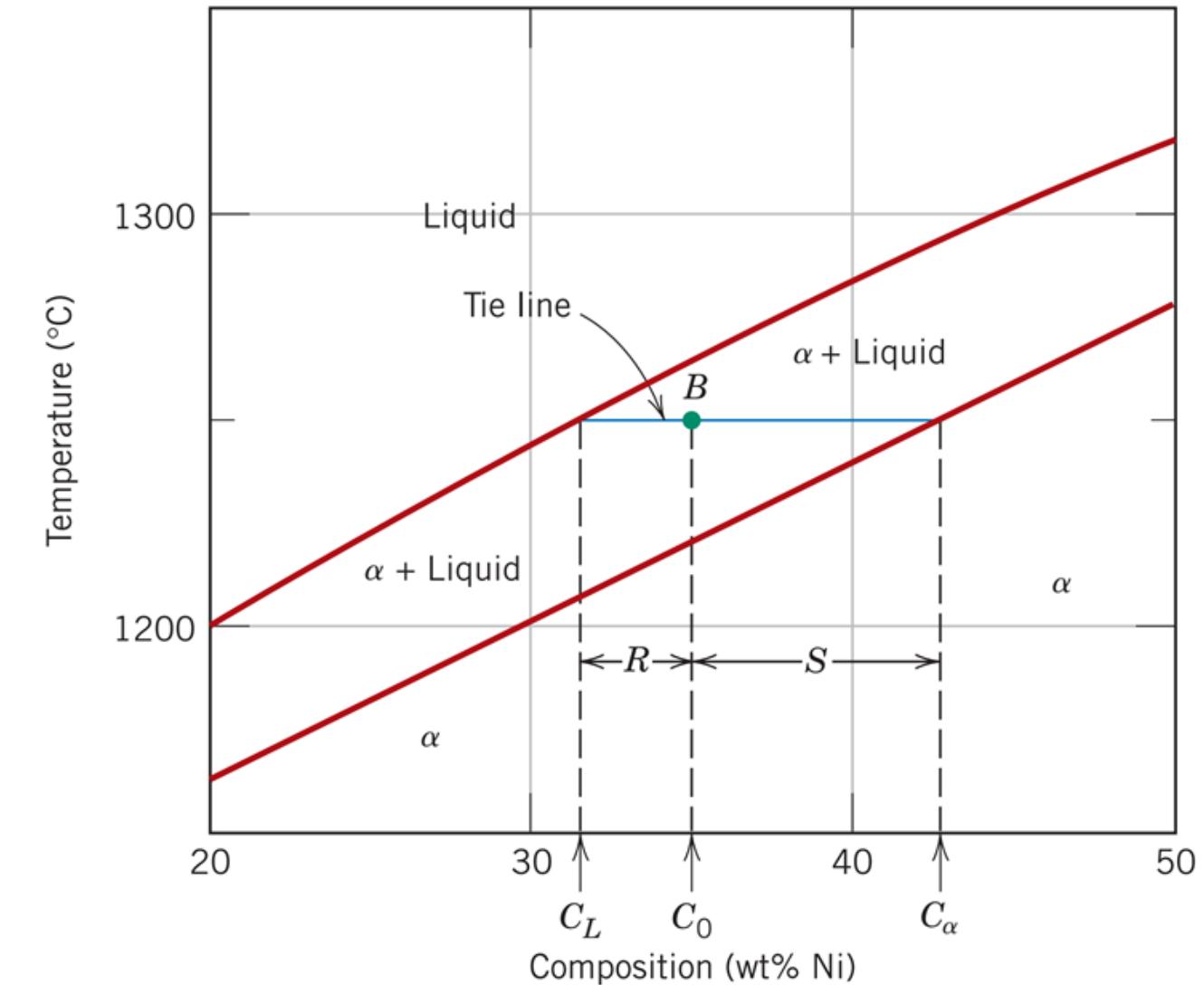
The Lever Rule

The lever rule derived from mass balance gives the relative amounts of the co-existing phases. It is derived as Tie line treated as lever arm, with the fulcrum as the overall composition.



Mass fractions be represented by w_L and w_α for the respective phases.

$$w_L = \frac{M_L}{M_L + M_\alpha} = \frac{S}{R + S} = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$



Interpretation of Phase Diagram

$C_o = 35\text{wt.\% Ni}$, $C_a = 42.5 \text{ wt.\% Ni}$, and $C_L = 31.5 \text{ wt.\% Ni}$

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

$$W_L = \frac{42.5 - 35}{42.5 - 31.5} = 0.68$$

$$W_\alpha = \frac{35 - 31.5}{42.5 - 31.5} = 0.32$$

For an alloy consisting of α and β phases, the volume fraction of the α phase, V_α ,

is defined as

$$V_\alpha = \frac{V_\alpha}{V_\alpha + V_\beta}$$

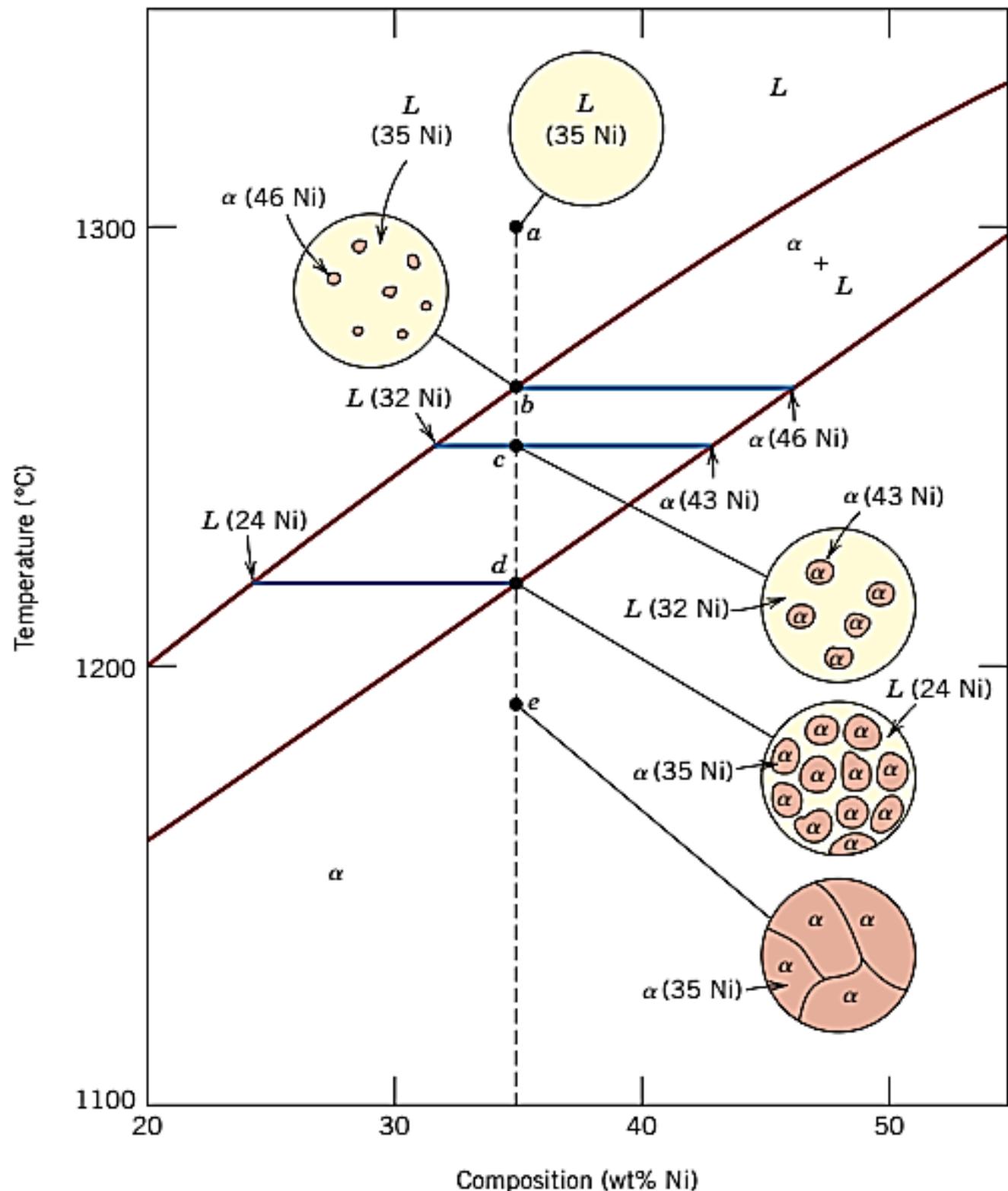
$$V_\alpha + V_\beta = 1$$

a phase volume fraction-dependence on volumes of α and β phases

Microstructures will vary on the cooling rate (i.e. processing conditions)

Equilibrium Cooling

1. Very slow cooling to allow phase equilibrium to be maintained during the cooling process.
2. Cooling rate \ll diffusion time.

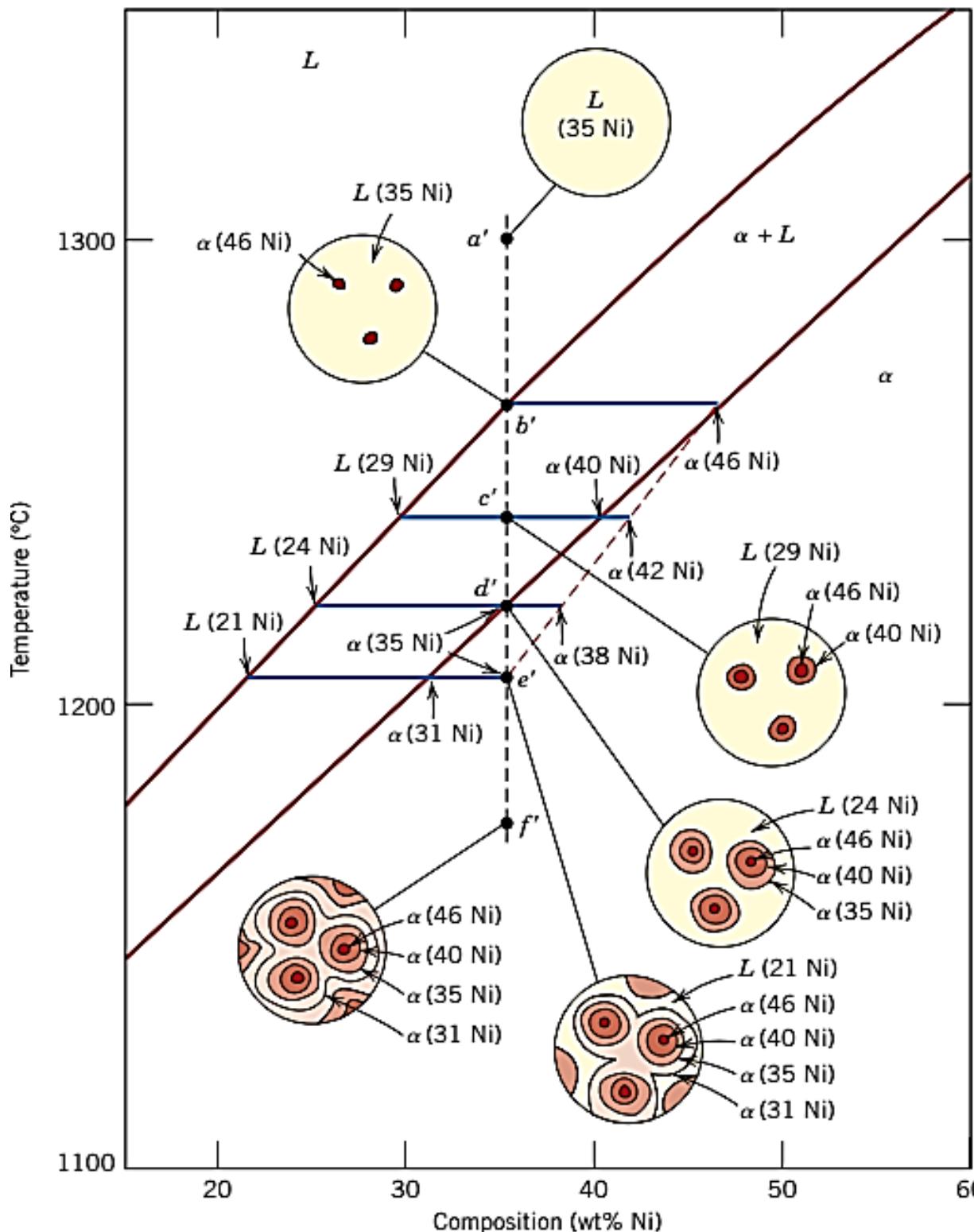


Development of microstructure in isomorphous alloys

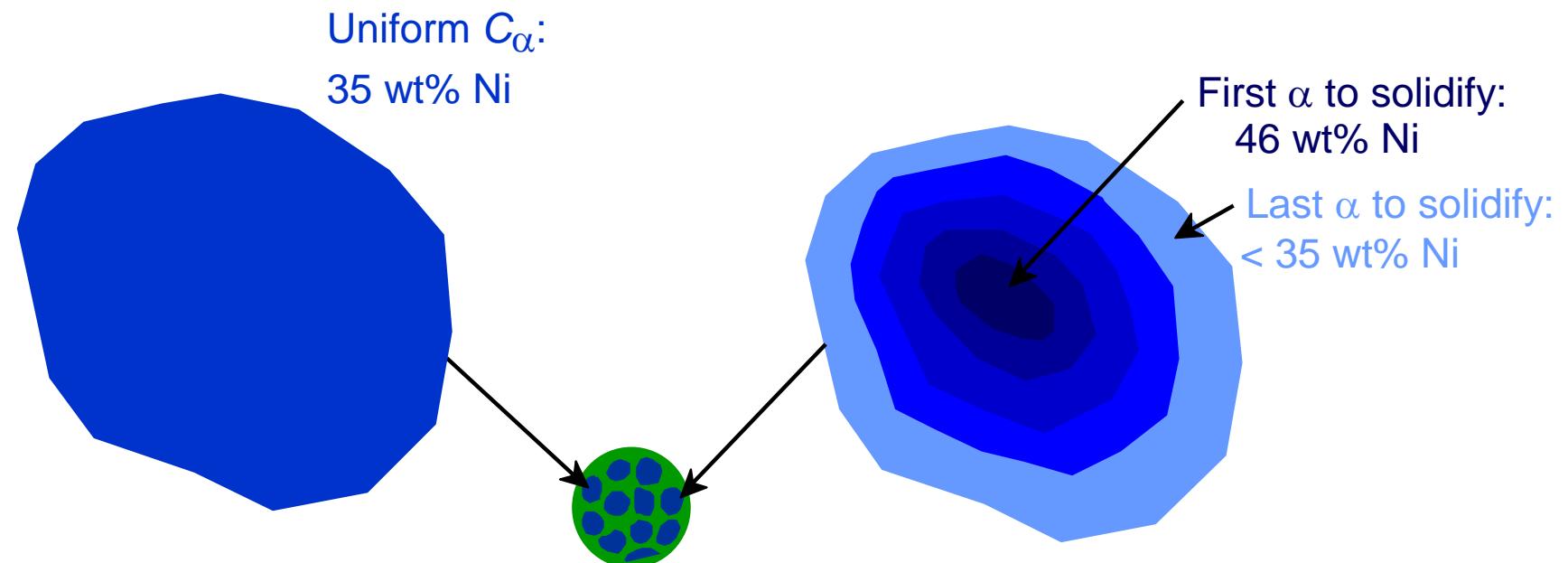
Non-equilibrium Cooling

- Fast cooling does not allow to allow phase equilibrium to be maintained during the cooling process.
- Cooling rate \gg diffusion time.

The centre of each grain, which is the first part to freeze, is rich in the high-melting element (e.g., nickel for this Cu–Ni system), whereas the concentration of the low-melting element increases with position from this region to the grain boundary. This is termed a **cored structure**, and gives rise to less than the optimal properties.



- C_α changes as we solidify.
- Cu-Ni case: First α to solidify has $C_\alpha = 46$ wt% Ni.
Last α to solidify has $C_\alpha = 35$ wt% Ni.
- Slow rate of cooling:
Equilibrium structure
- Fast rate of cooling:
Cored structure



Summary

1. Phase diagrams are useful tools to determine:
 - the number and types of phases present,
 - the composition of each phase,
 - and the weight fraction of each phase given the temperature and composition of the system.
2. Isomorphous phase diagrams has same structure and same morphology without any solubility limit.
3. The microstructure of an alloy depends on
 - its composition, and
 - whether or not cooling rate allows for maintenance of equilibrium.