MLL 100

Introduction to Materials Science and Engineering

Lecture-11 (January 29, 2022)

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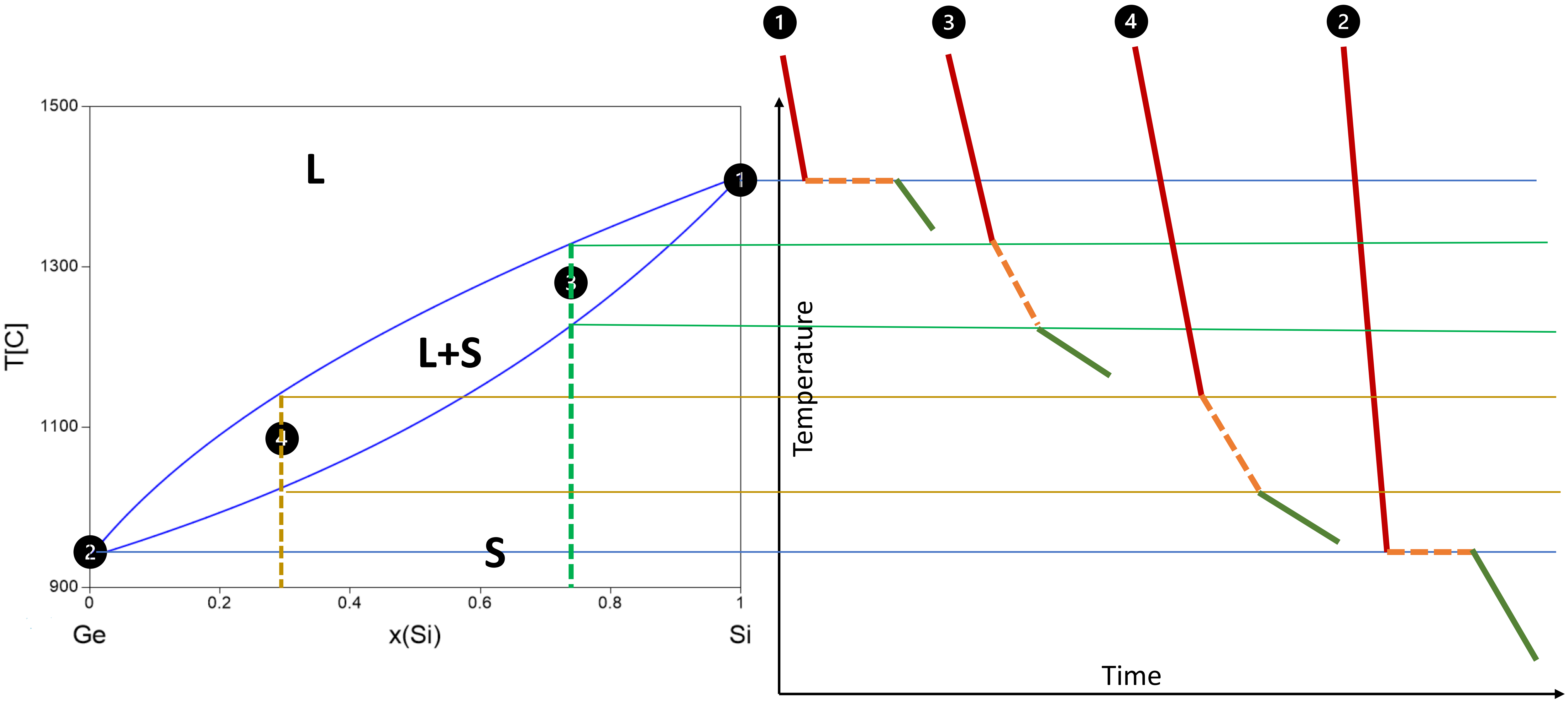
What have we learnt in Lecture-10?

- Condensed Gibb’s phase rule
- Tie-line
- Lever rule

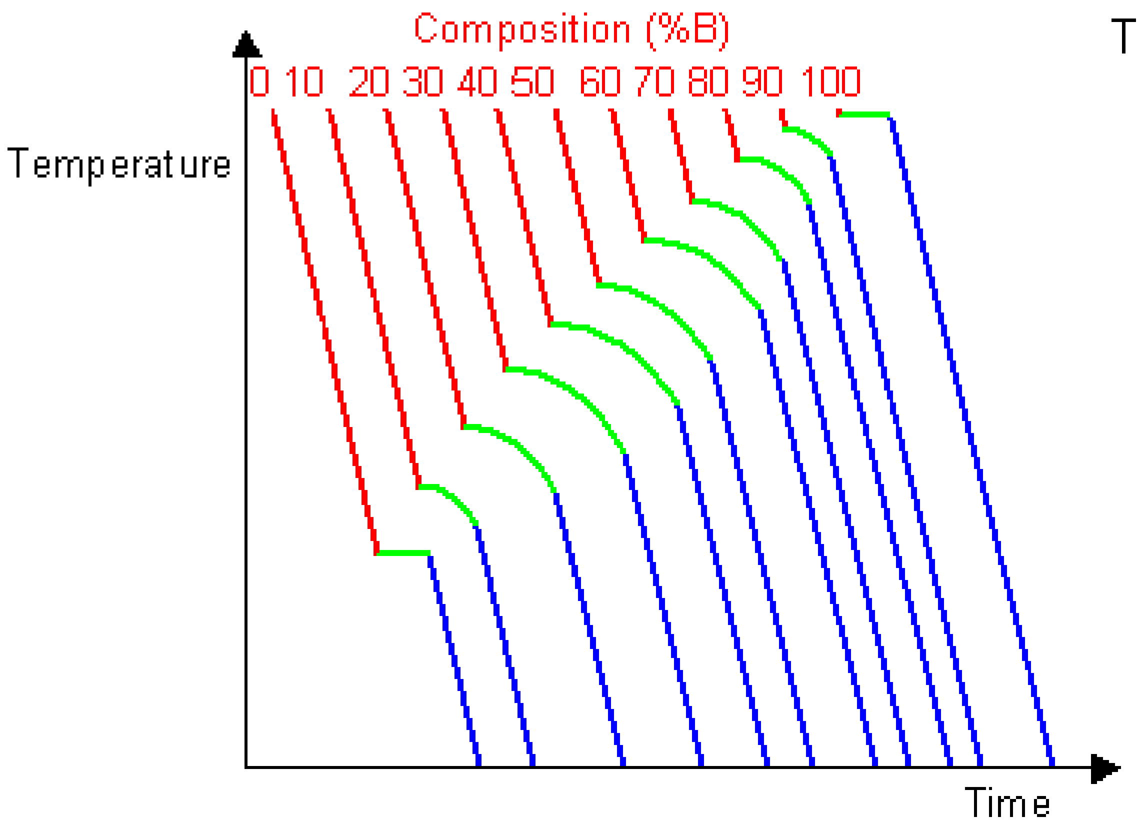
How to construct a phase diagram?

- Determination of phase boundary ---- > liquidus, solidus, solvus, etc.

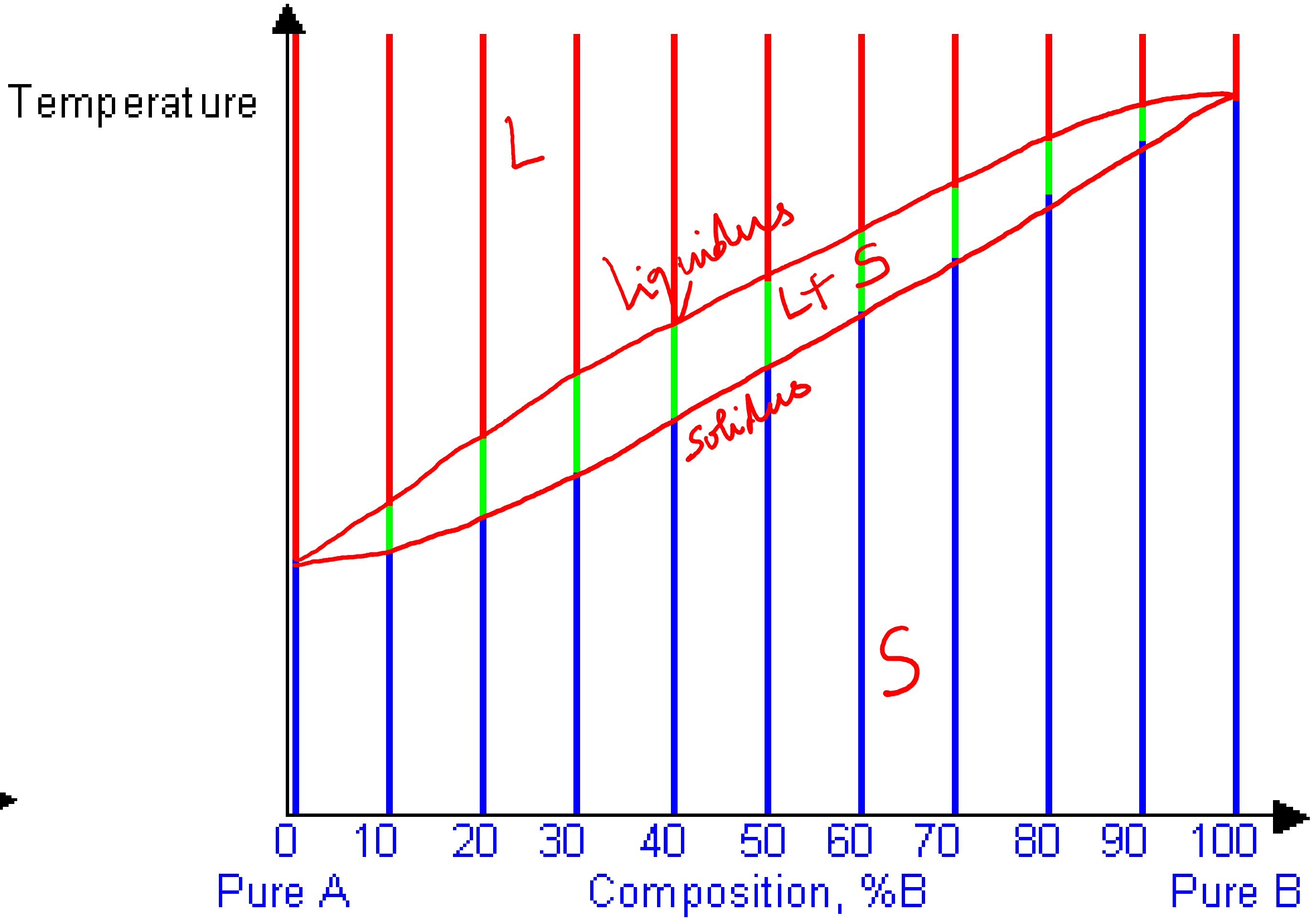
Cooling curve



- Pure metals melt at a single temperature (melting point).
- Alloys melt over a range of temperature.

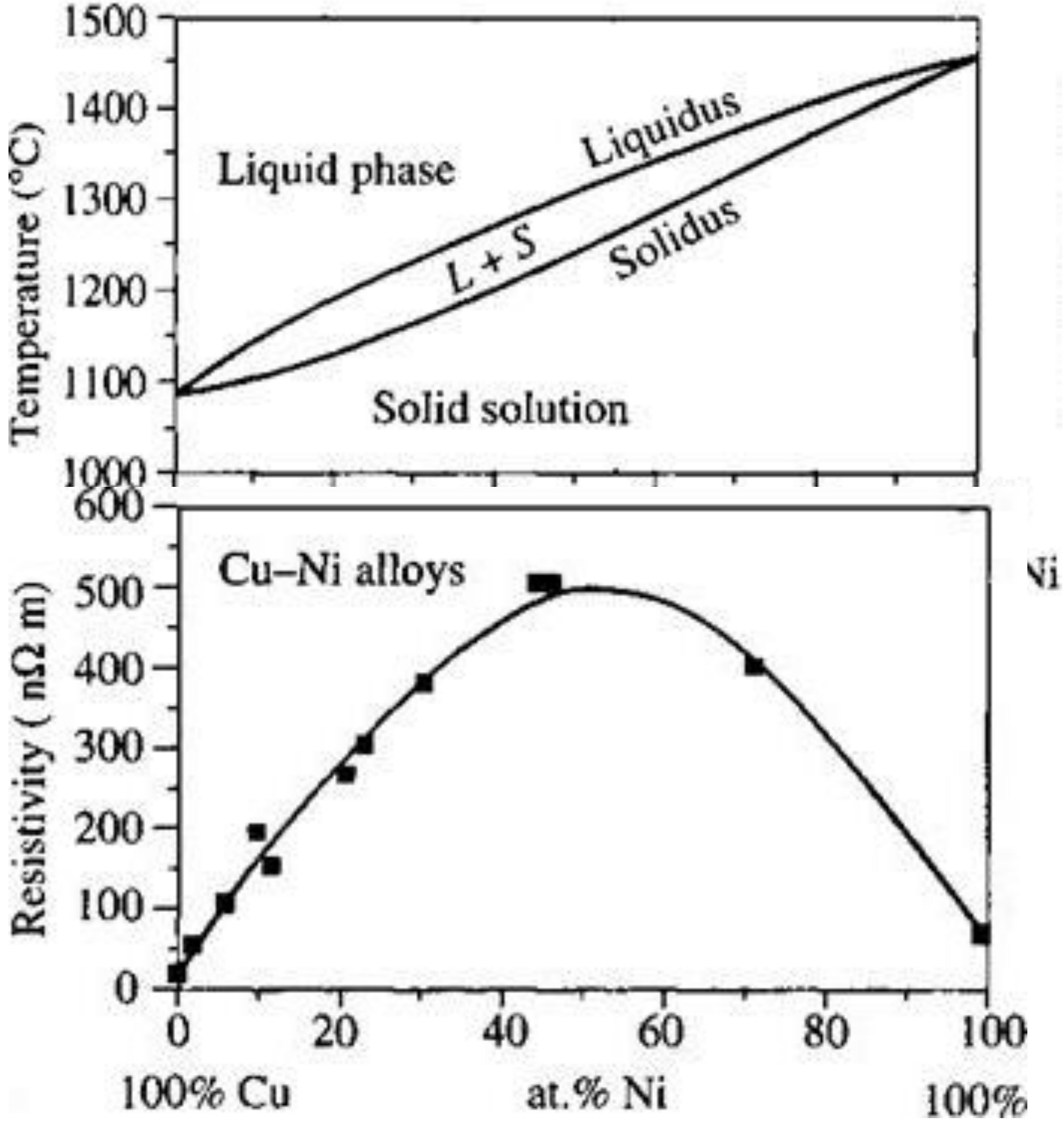


Composition (%B)
0 10 20 30 40 50 60 70 80 90 100
Temperature
Time



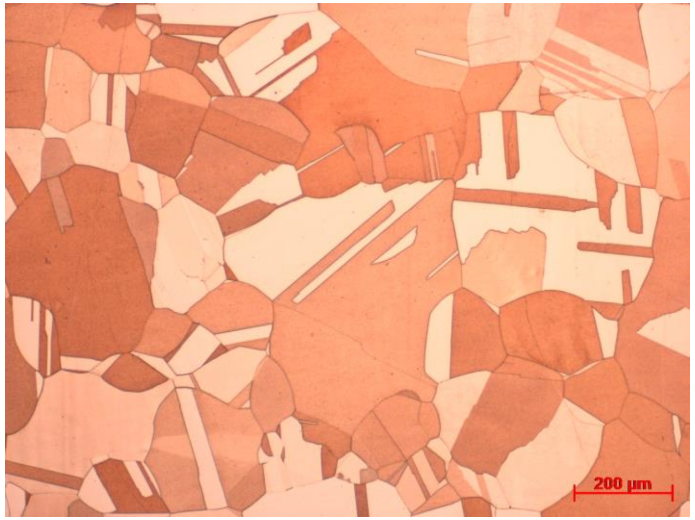
Temperature
L
Liquidus
L+S
Solidus
S
0 10 20 30 40 50 60 70 80 90 100
Pure A
Composition, %B
Pure B

Variation of electrical resistivity of alloys as a function of composition



………. Can you think of any other method using which you may be able to identify the phase boundaries?

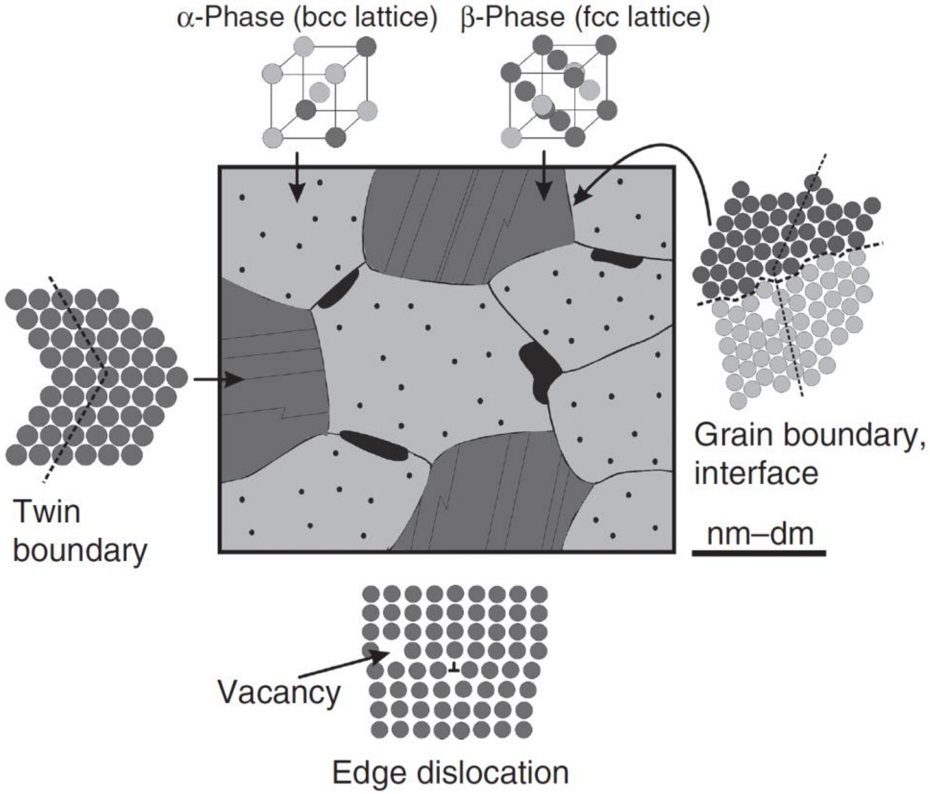
Microstructure

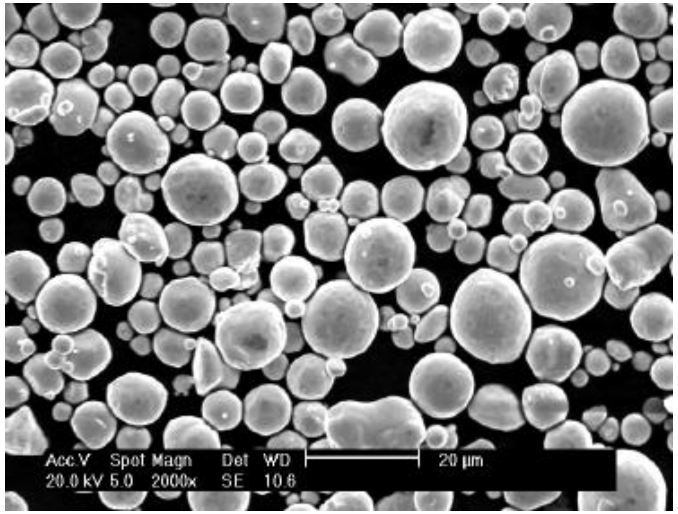


Microstructure obtained through an Optical microscopy

Structural features observed at the micron level in a material

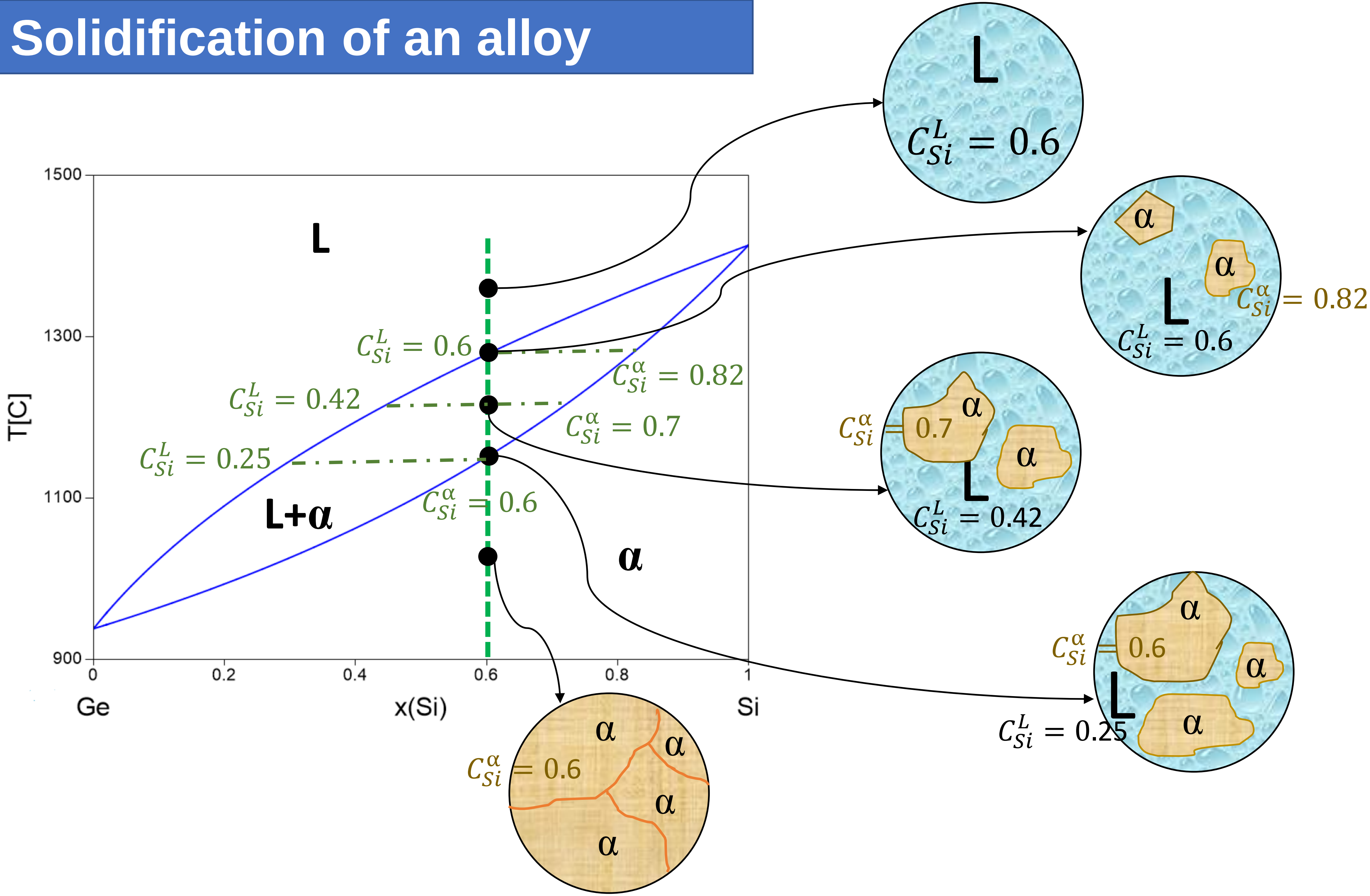
- Phases, Defects, Phase morphology

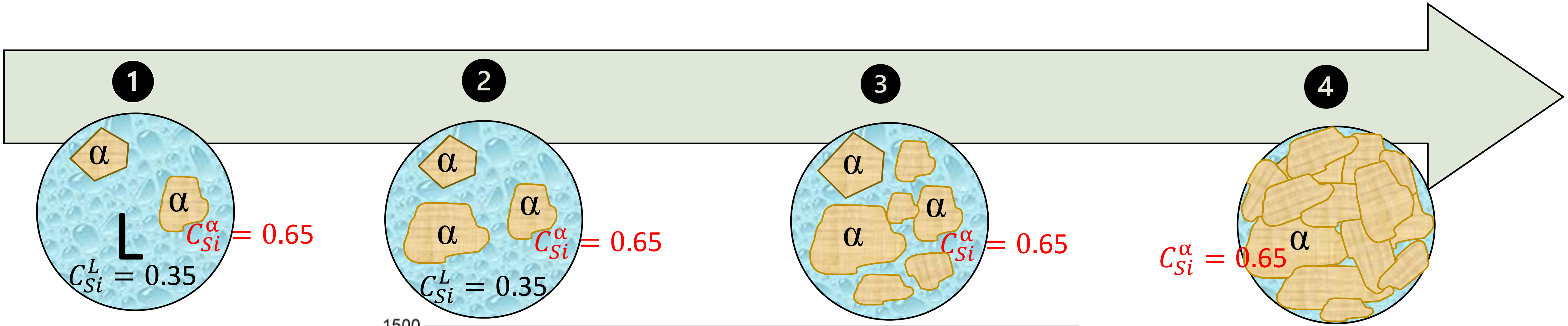


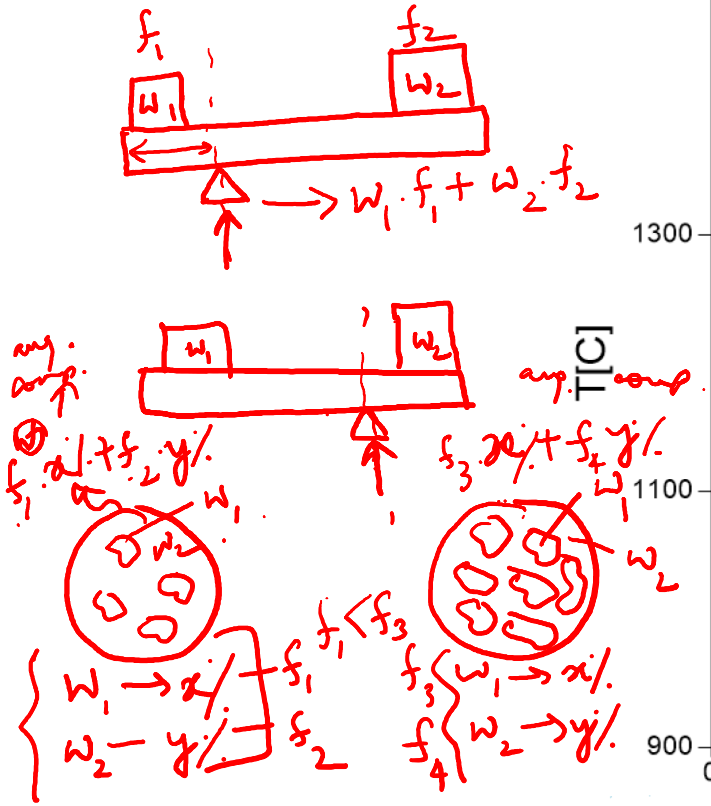


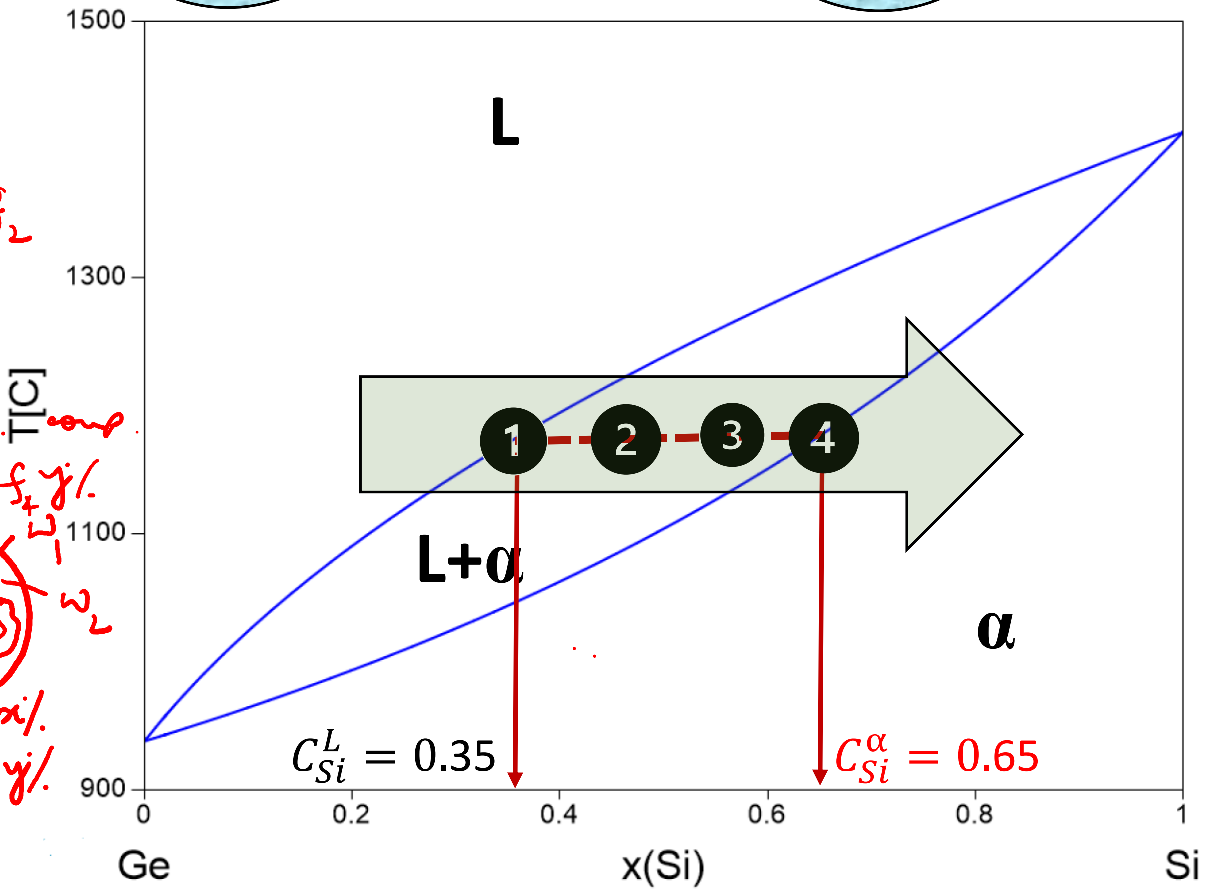
Microstructure obtained through a Scanning Electron Microscopy (SEM)

Solidification of an alloy







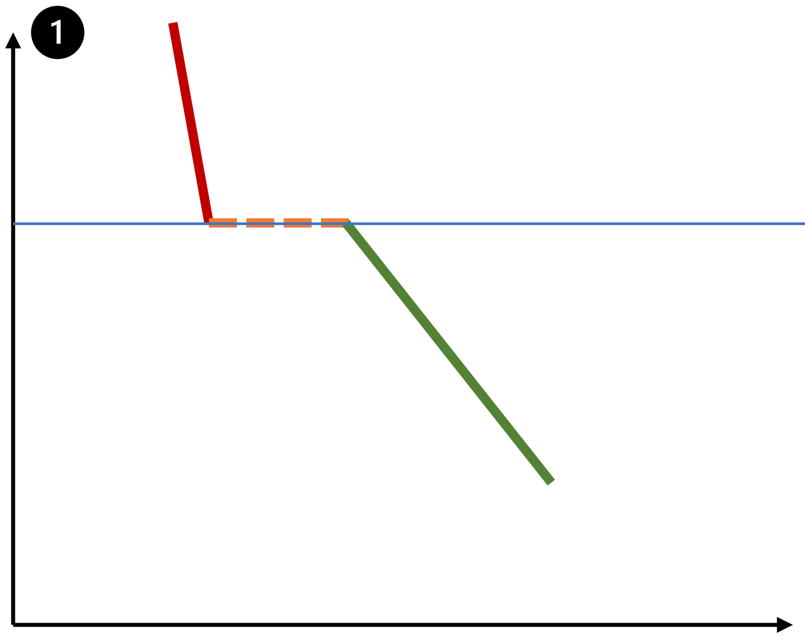


- Alloys along this horizontal line, will consist of two phases, liquid and alpha, whose respective compositions will remain same.
- The difference will be in the fraction of these two phases for different alloys

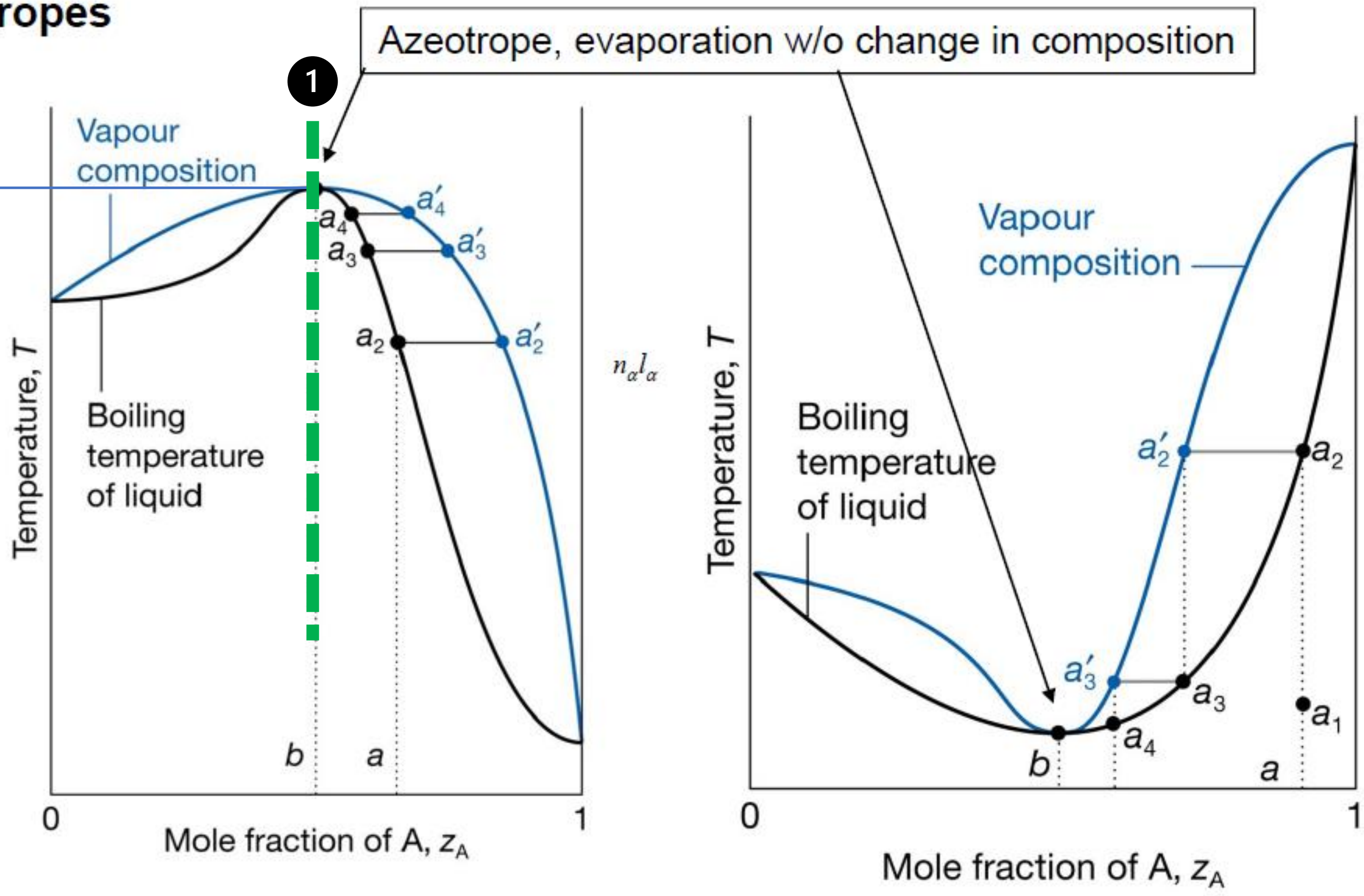
Azeotropes

- Ethanol-water
- Nitric acid-water
- Benzene-water

How will a cooling curve look like for an alloy '1'?

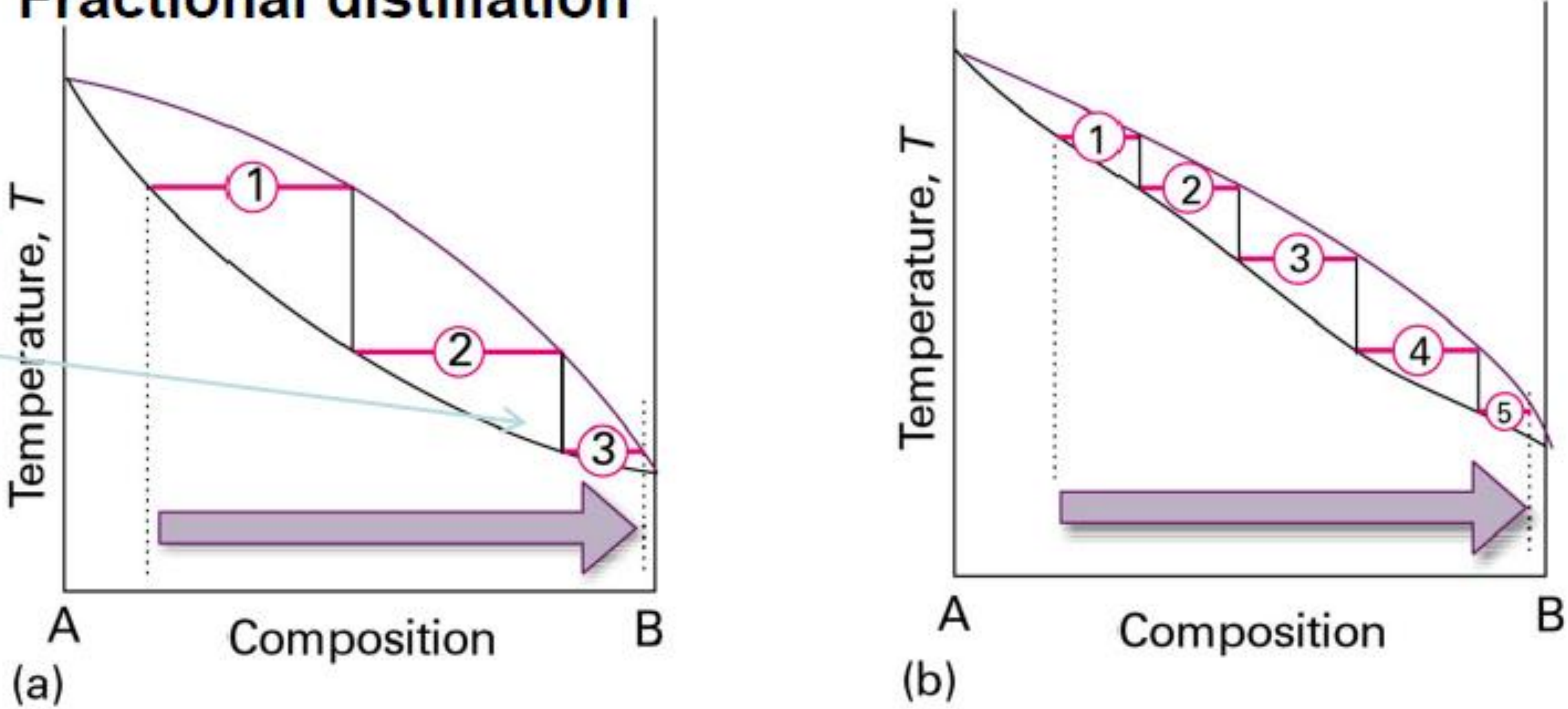


•**Azeotropes**

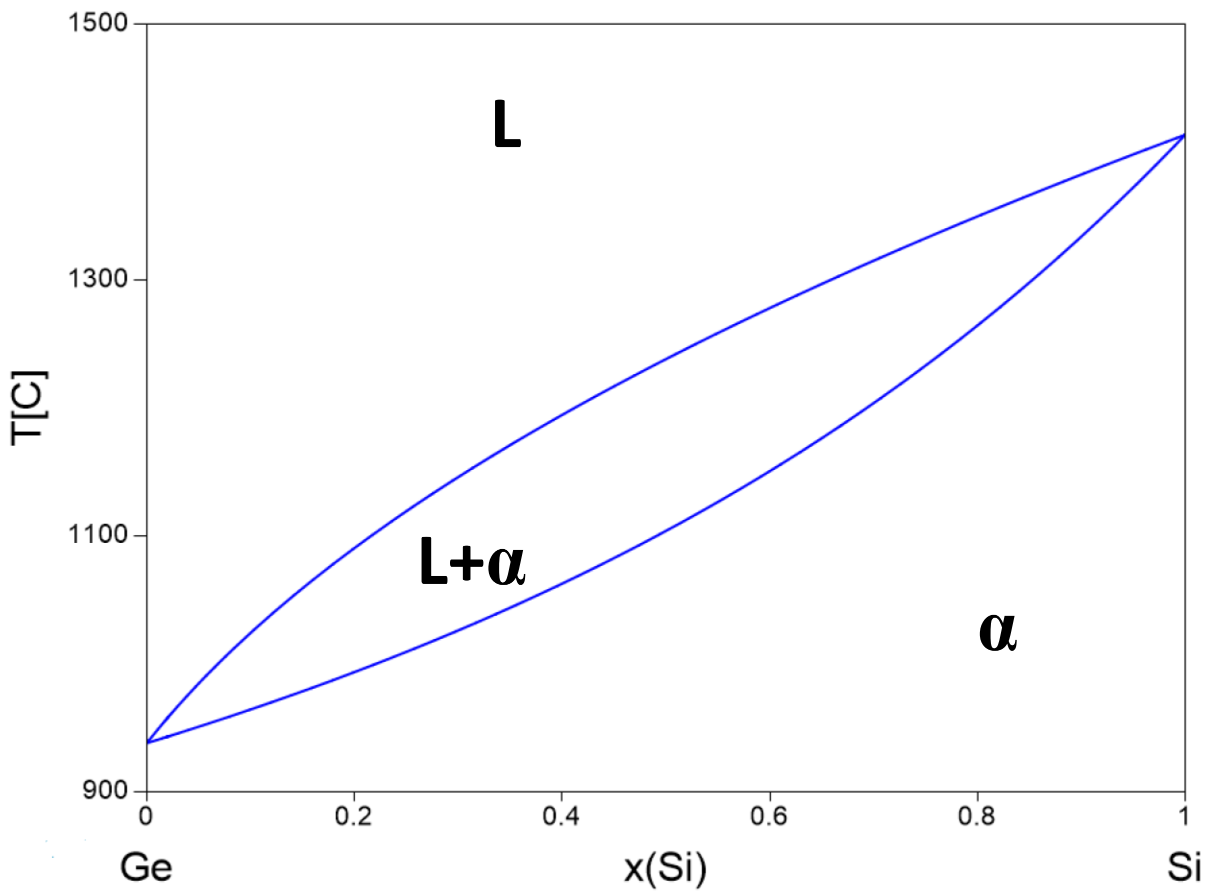


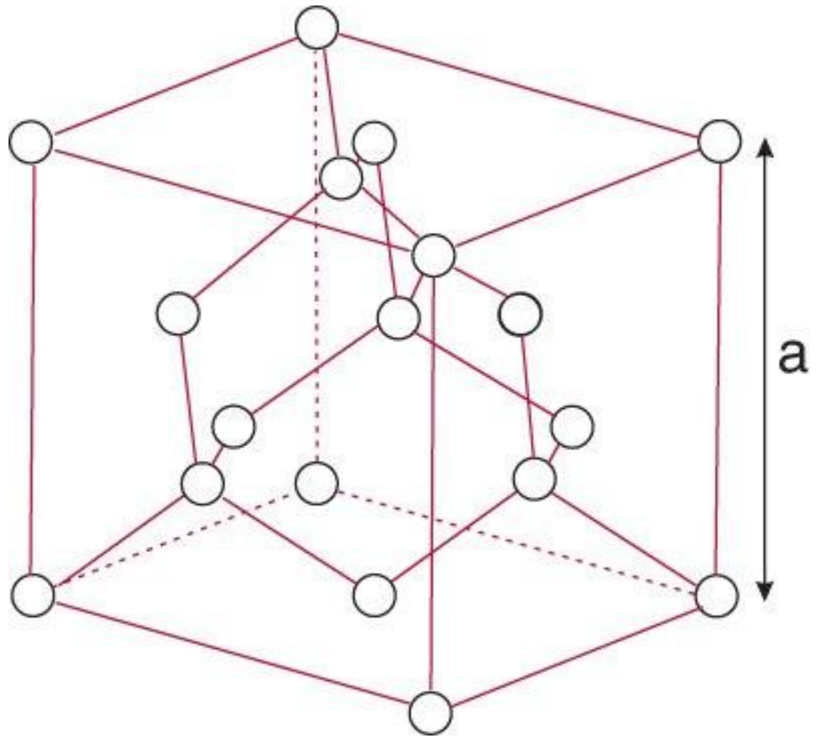
Fractional distillation

number of theoretical plates



Solid solution





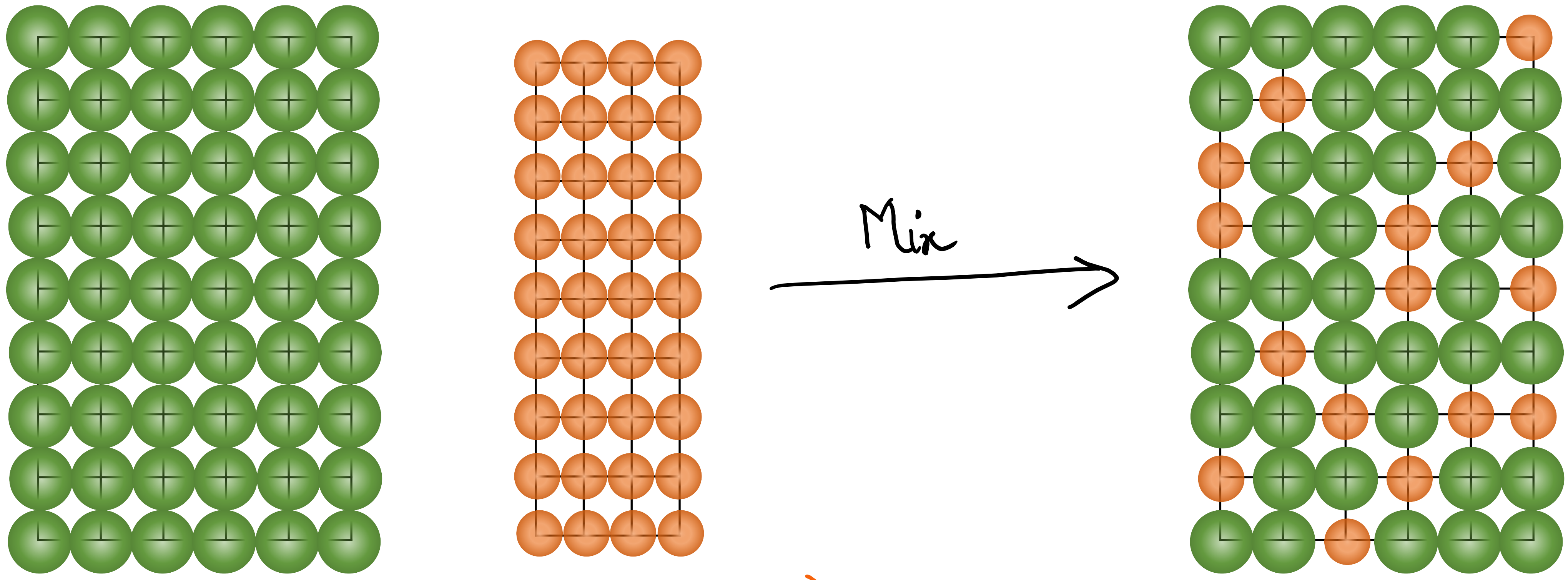
Diamond cubic structure

Solid solution

- Consider a system with a total of one mole of atoms

  (X_R and X_G : mole fractions of element R and G respectively)

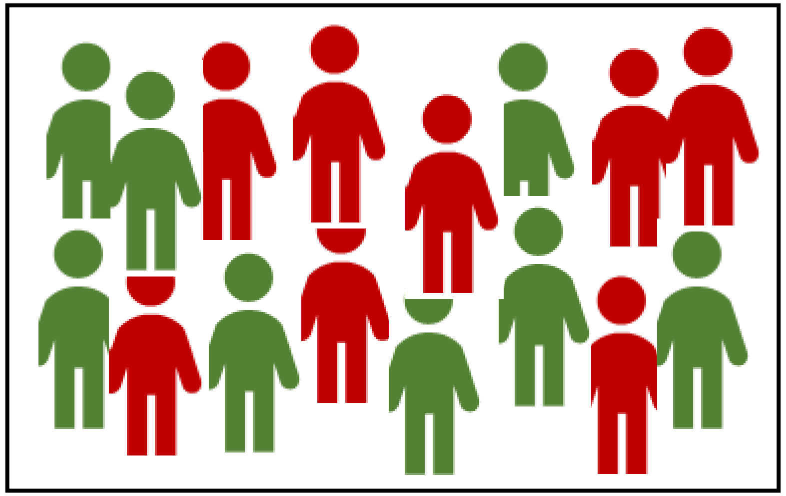
$$X_R + X_G = 1$$



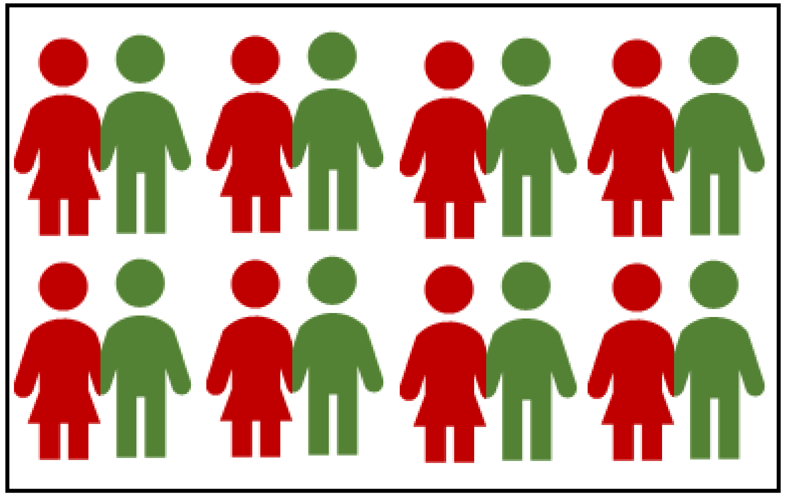
$\underbrace{(X_G \text{ moles of 'G'}) \quad (X_R \text{ moles of R})}_{\text{(Before mixing)}}$

$\underbrace{(1 \text{ mole of solid solution})}_{\text{(After mixing)}}$

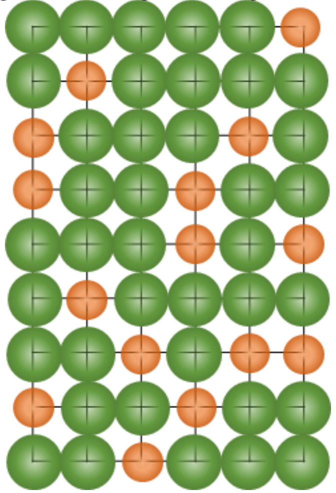
Solid solution (Random configuration): *'R' and 'G' care the least about their environments.*

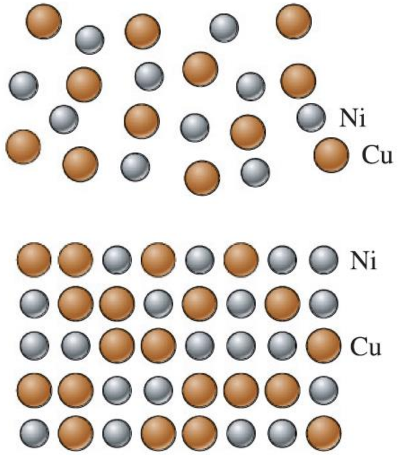


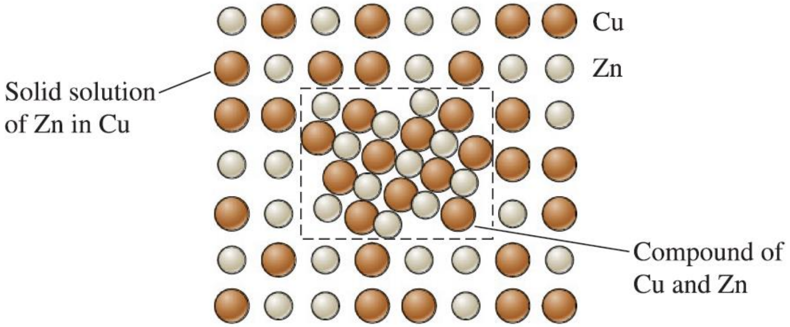
Compound formation (Ordered configuration): *'R' and 'G' feel strongly comfortable in other's space.*



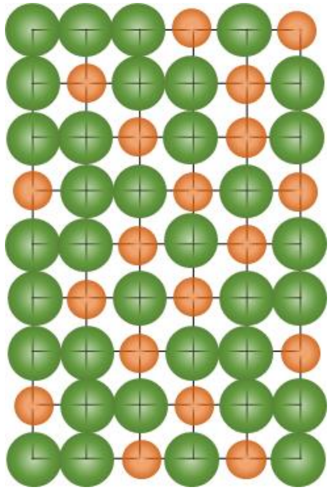
Solid solution (No preference for any bond)







Intermetallic compound (Unlike bonds are preferred)

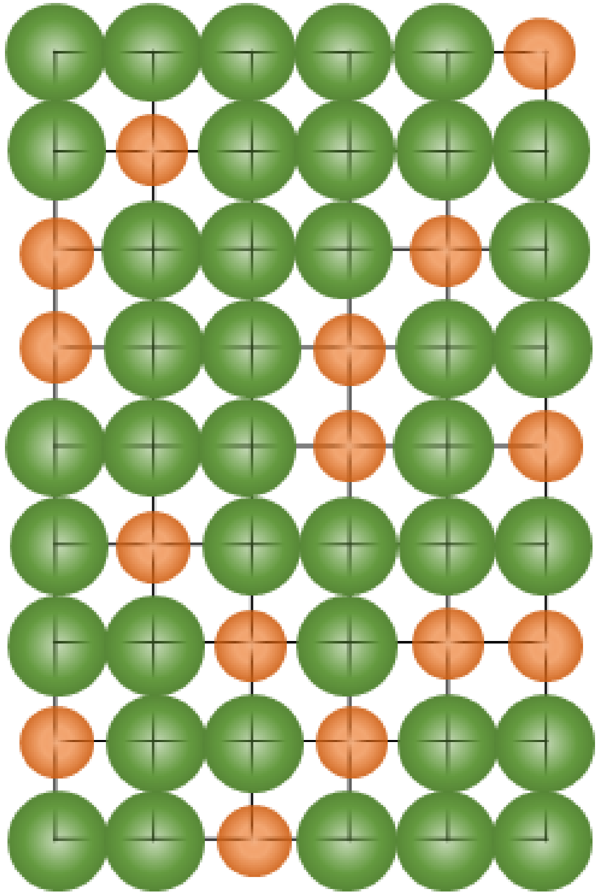


- Variation in composition
- Crystal structure same as that of one of the solid components.

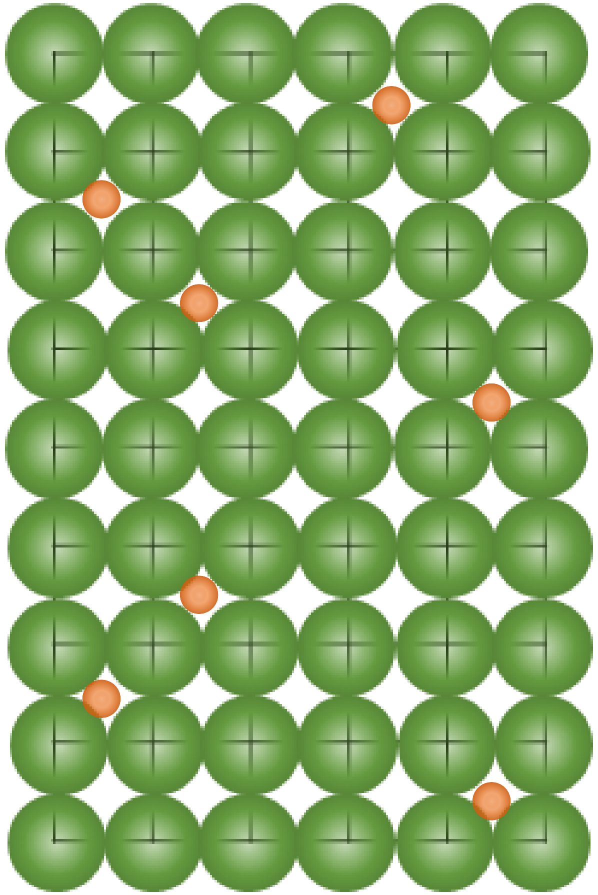
- Fixed composition
- Crystal structure different than those of the solid components.

Types of Solid solution

Substitutional Solid solution



Interstitial Solid solution



Hume Rothery rule

(i) Size factor

When the atomic radii of solute and solvent differ by less than 15%, solid solution is favourable, which otherwise will result in lattice strain.

(ii) Crystal structure

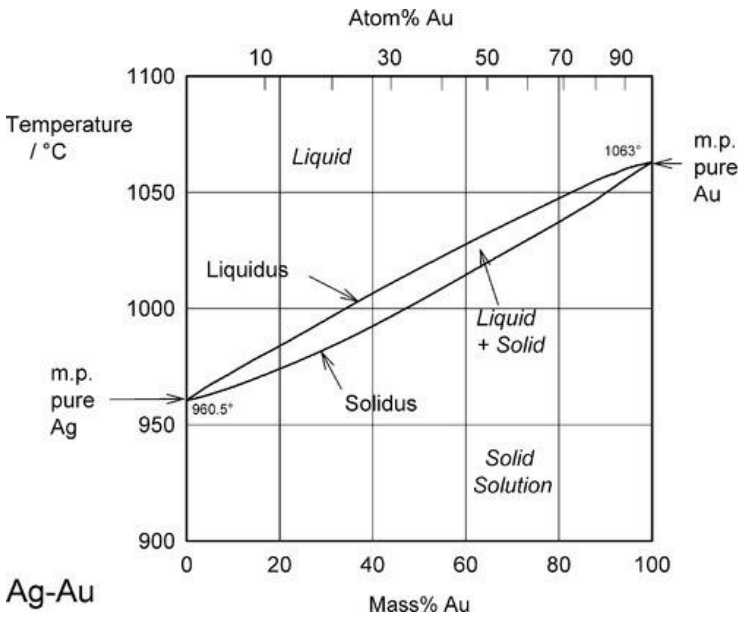
Crystal structures of both the components should be the same.

(iii) Valency

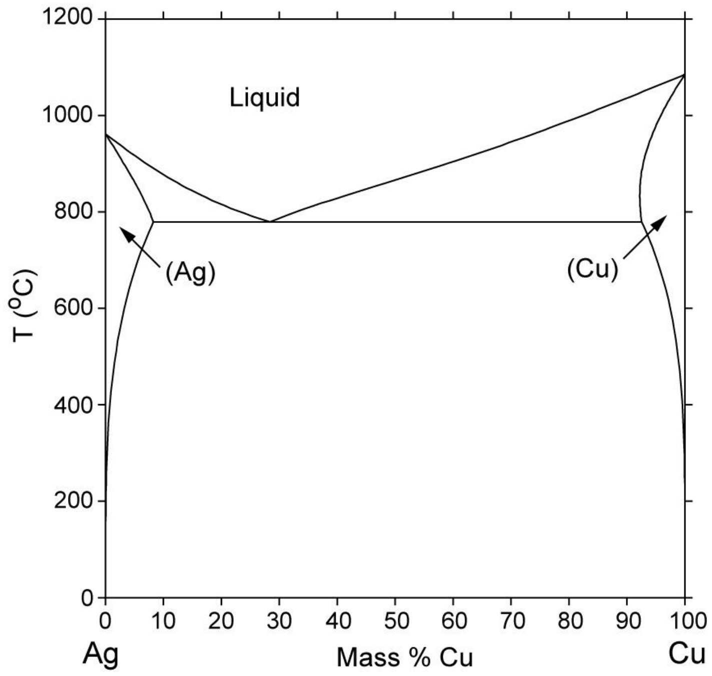
If valency is the same for both the solvent and solute, then a complete miscibility is possible.
Solubility is higher when the solvent has a higher valence.

(iv) Electronegativity

Similar electronegativity favours a higher solubility. The higher the difference, the greater the possibility for the formation of new compound phase.



Elements	Atomic size	Electronegativity	Crystal structure	Valency
Cu	140 pm	1.9	FCC	+2
Ni	149 pm	1.91	FCC	+2
	$\Delta AS = 6\%$			



Cu	140 pm	1.9	FCC	+2
Ag	165 pm	1.93	FCC	+1
	$\Delta AS = 18\%$			