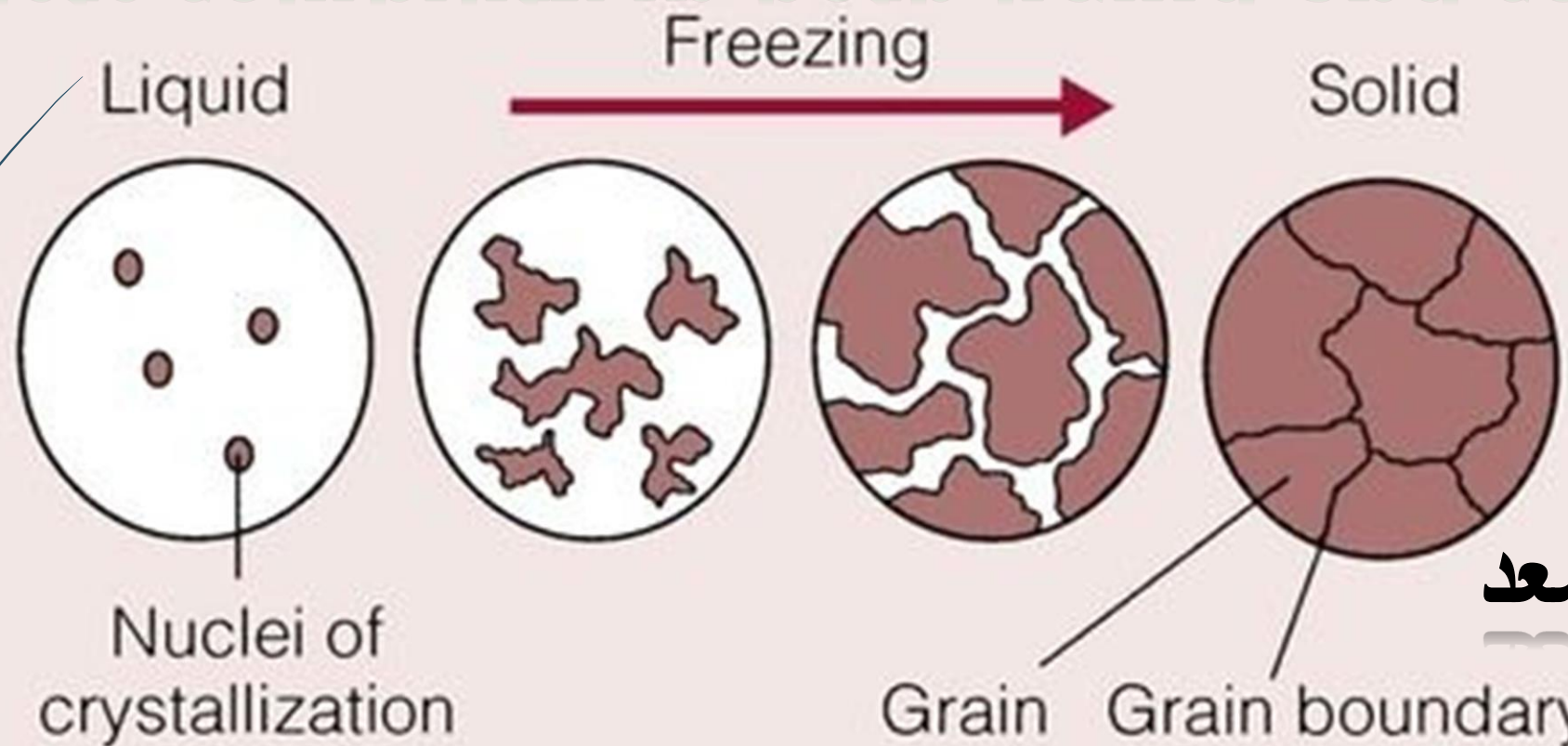


Lecture No. 2

Complete solubility in both liquid and solid states

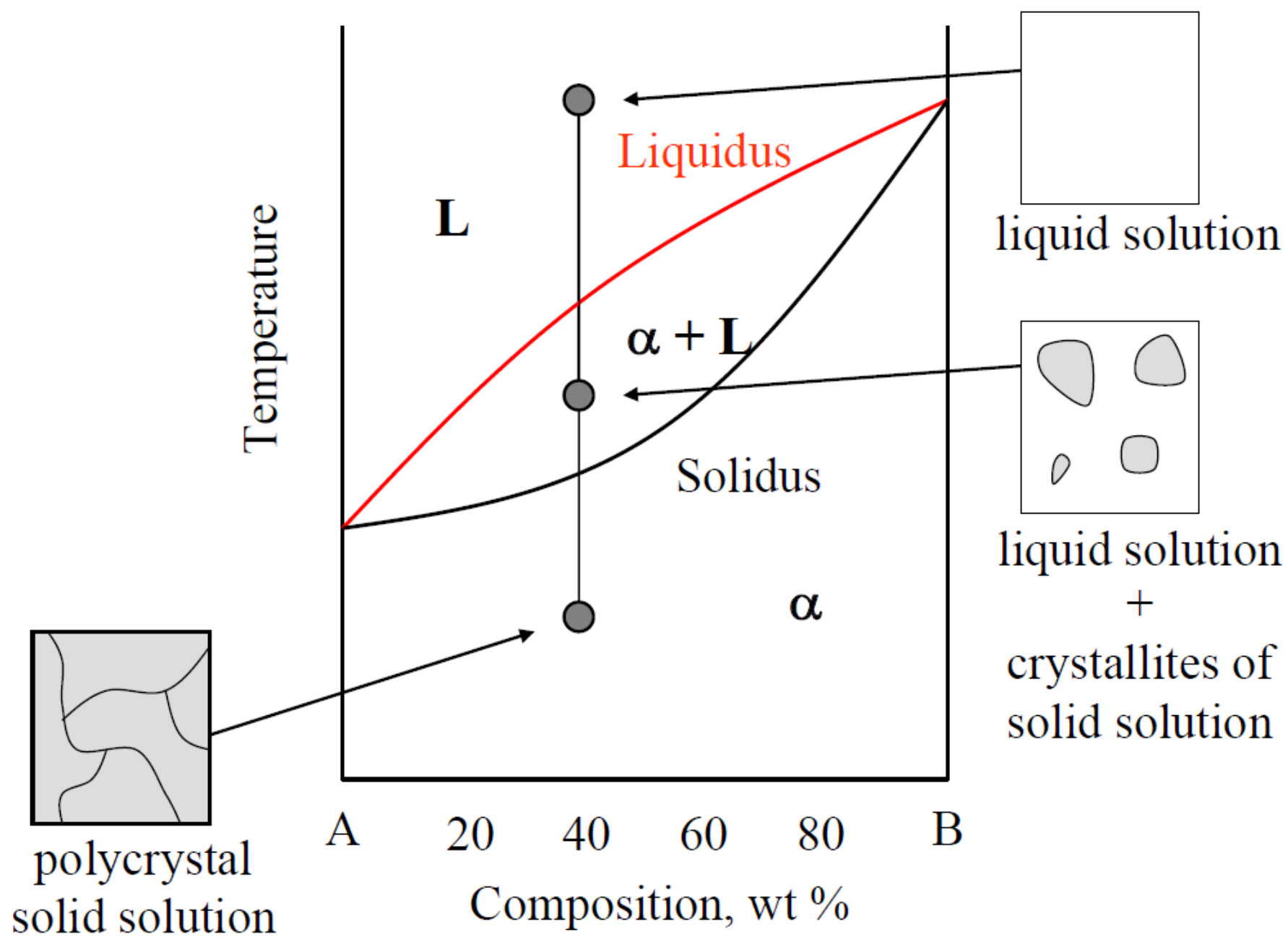


د. محمد سعد



In one-component system melting occurs at a well-defined melting temperature.

In multi-component systems melting occurs over the range of temperatures, between the solidus and liquidus lines. Solid and liquid phases are at equilibrium with each other in this temperature range.



Interpretation of a binary phase diagrams

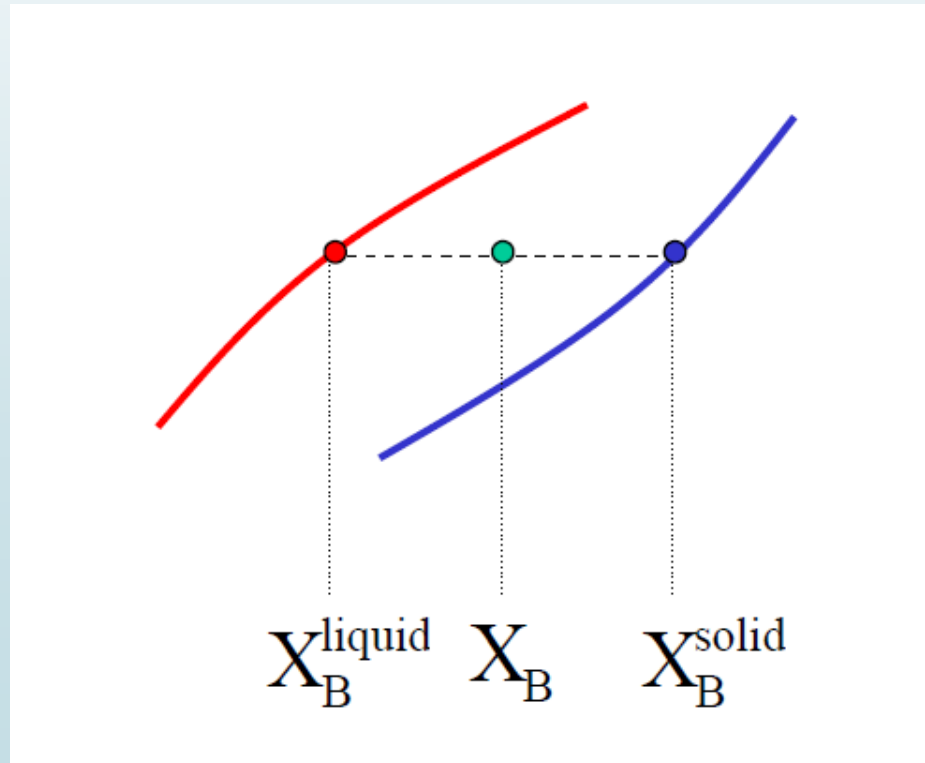
For a given temperature and composition we can use phase diagram to determine:

- 1) The phases that are present
- 2) Compositions of the phases
- 3) The relative fractions of the phases

Finding the composition in a two phase region:

1. Locate composition and temperature in diagram
2. In two phase region draw the **tie line** or isotherm
3. Note intersection with phase boundaries. Read compositions at the intersections.

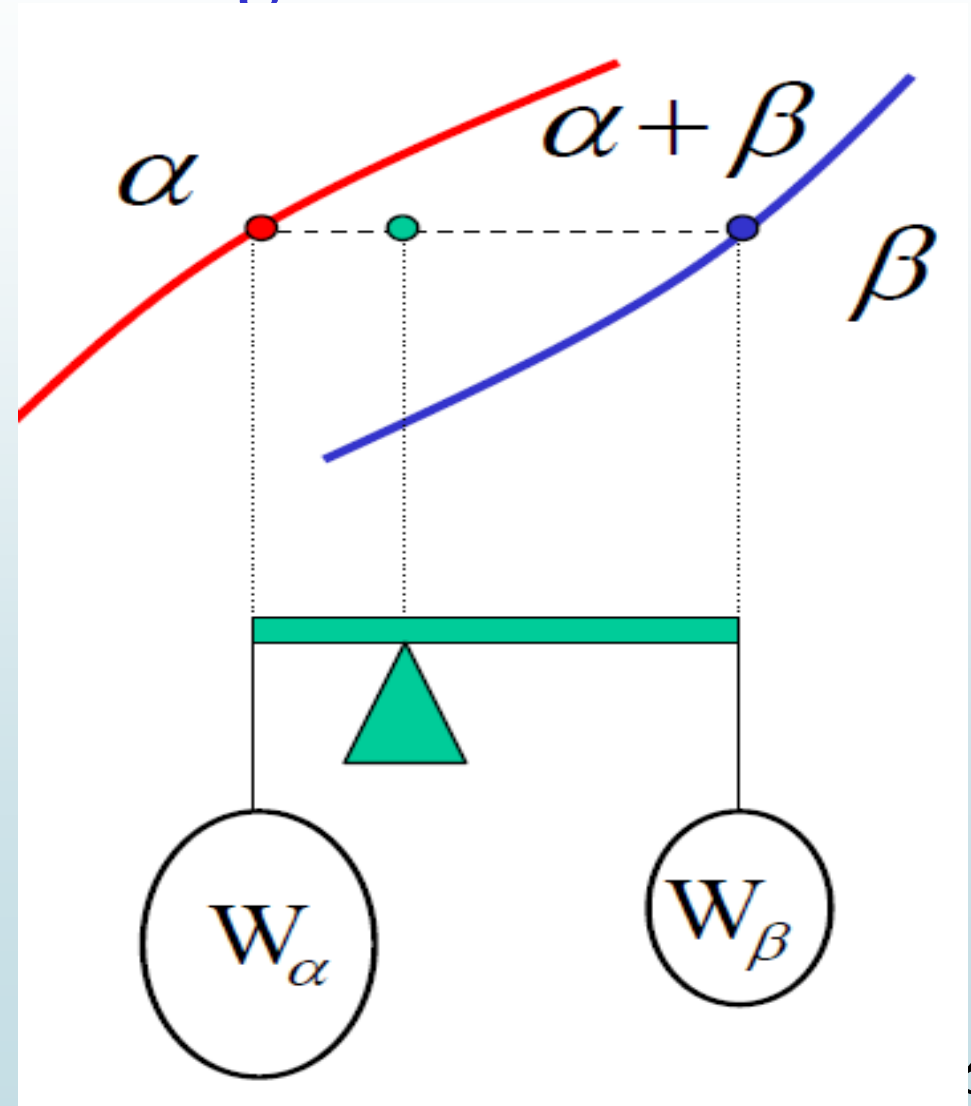
The liquid and solid phases have these compositions.



The lever rule

Finding the amounts of phases in a two phase region:

1. Locate composition and temperature in diagram
2. In two phase region draw the tie line or isotherm
3. Fraction of a phase is determined by taking the length of the tie line to the phase boundary for **the other phase**, and dividing by the total length of tie line



Derivation of the lever rule

1) All material must be in one phase or the other:

$$W_{\alpha} + W_L = 1$$

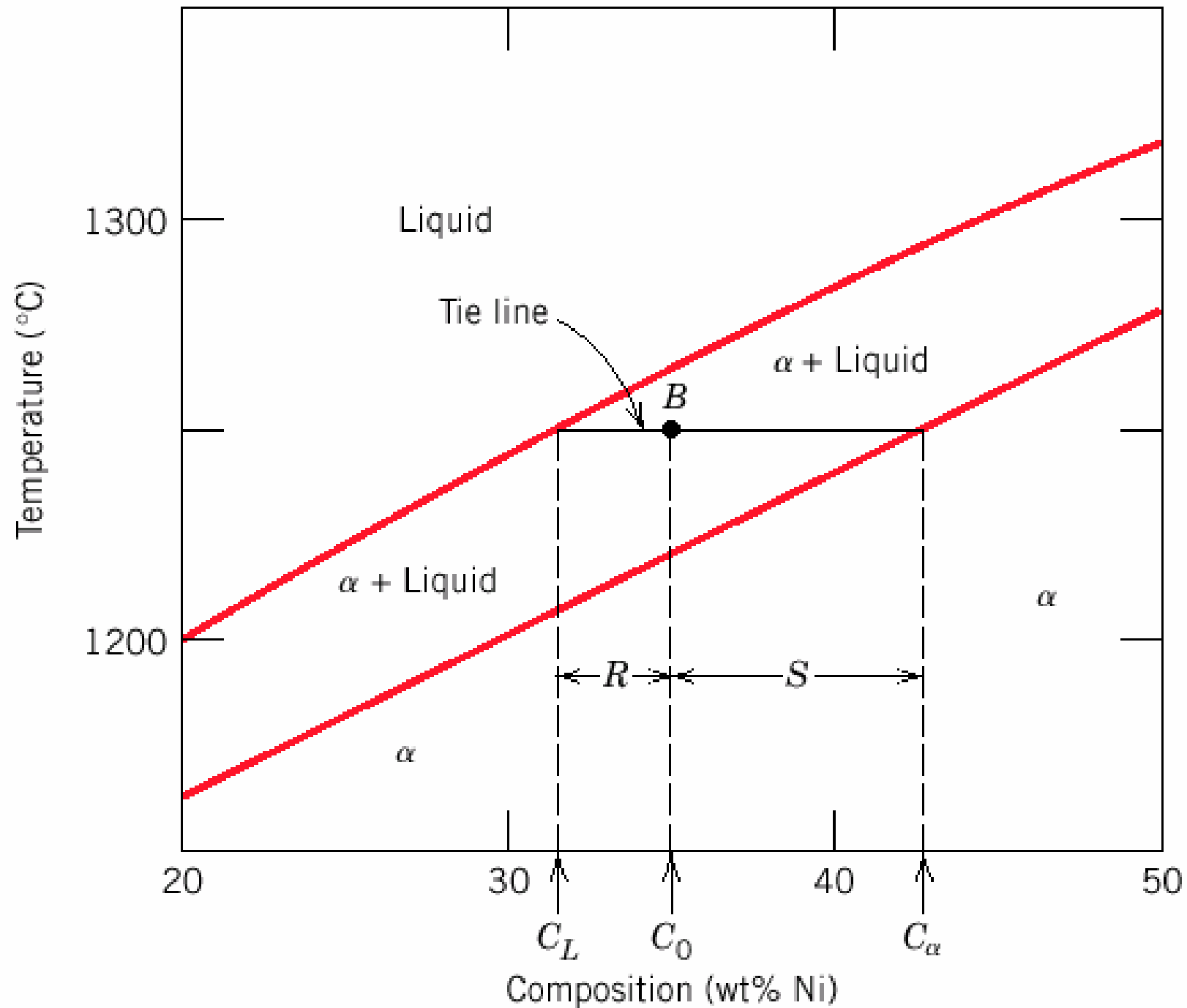
2) Mass of a component that is present in both phases equal to the mass of the component in one phase + mass of the component in the second phase:

$$W_{\alpha}C_{\alpha} + W_L C_L = C_o$$

3) Solution of these equations gives us the lever rule.

$$W_L = (C_{\alpha} - C_o) / (C_{\alpha} - C_L)$$

$$W_{\alpha} = (C_o - C_L) / (C_{\alpha} - C_L)$$

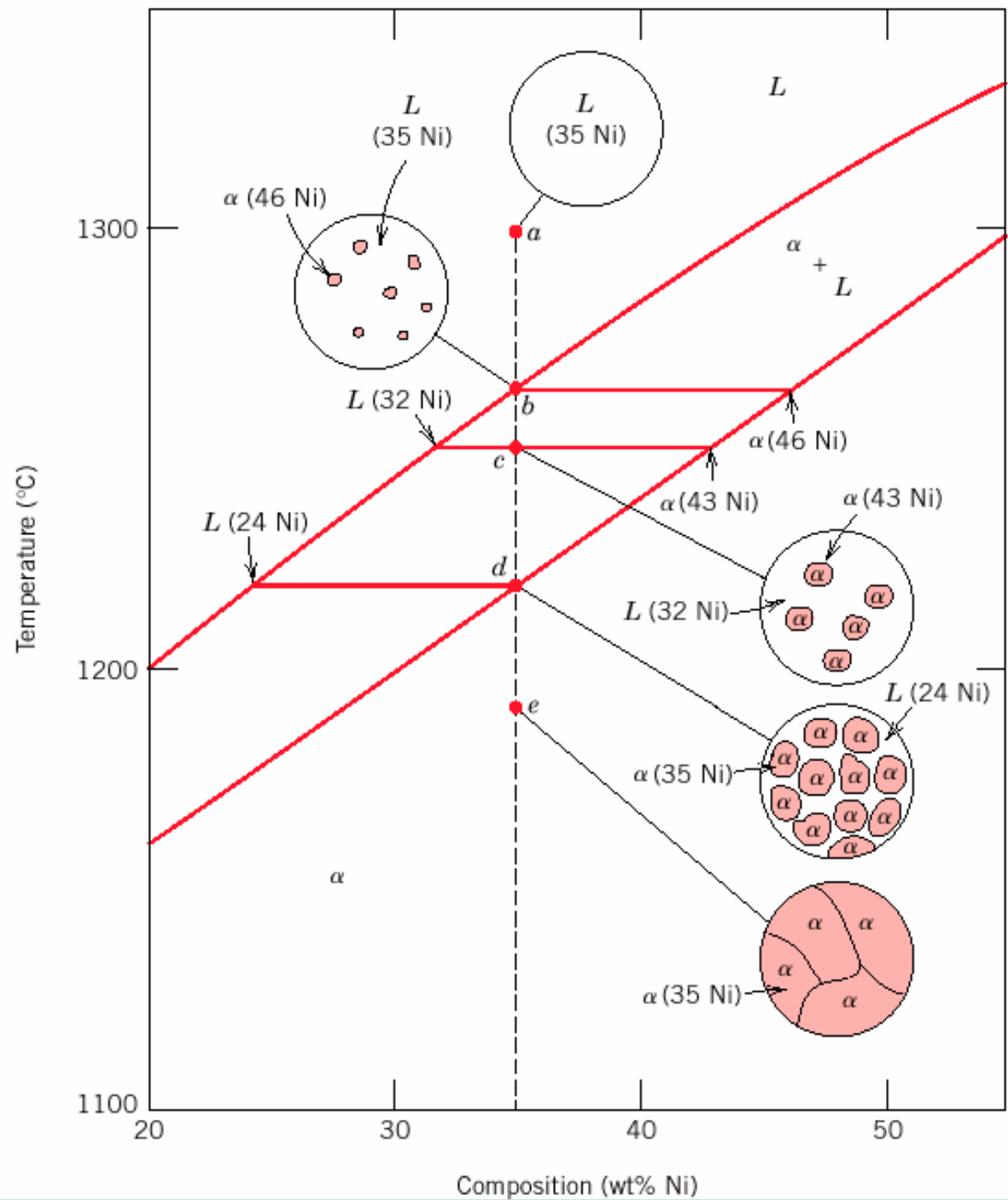


$C_o = 35 \text{ wt. } \%, C_L = 31.5 \text{ wt. } \%, C_\alpha = 42.5 \text{ wt. } \%$

Mass fractions:

$$W_L = S / (R+S) = (C_\alpha - C_o) / (C_\alpha - C_L) = 0.68$$

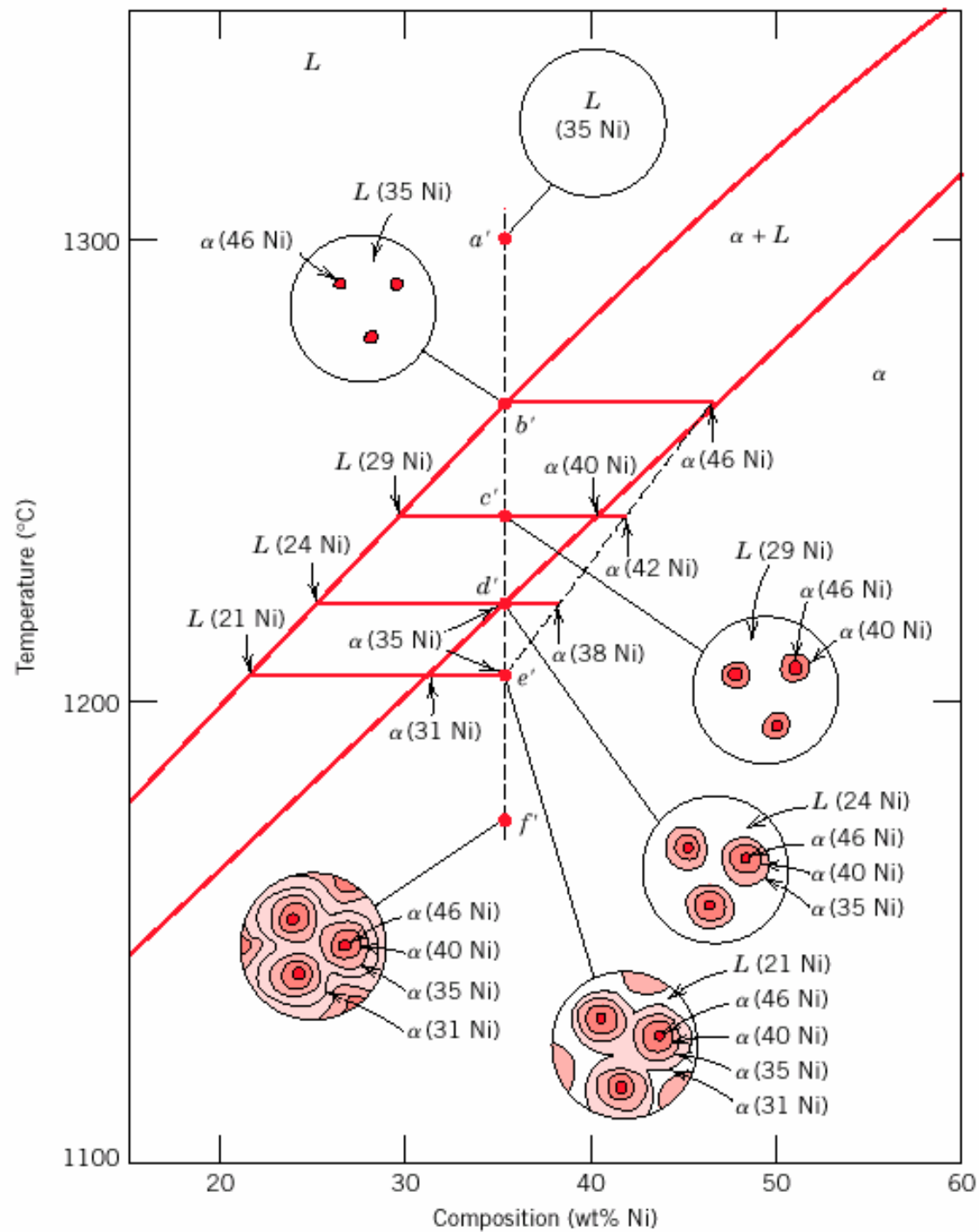
$$W_\alpha = R / (R+S) = (C_o - C_L) / (C_\alpha - C_L) = 0.32$$



Development of microstructure in isomorphous alloys

Equilibrium (very slow) cooling

- Solidification in the solid + liquid phase occurs gradually upon cooling from the liquidus line.
- The composition of the solid and the liquid change gradually during cooling (as can be determined by the tie-line method.)
- Nuclei of the solid phase form and they grow to consume all the liquid at the solidus line.



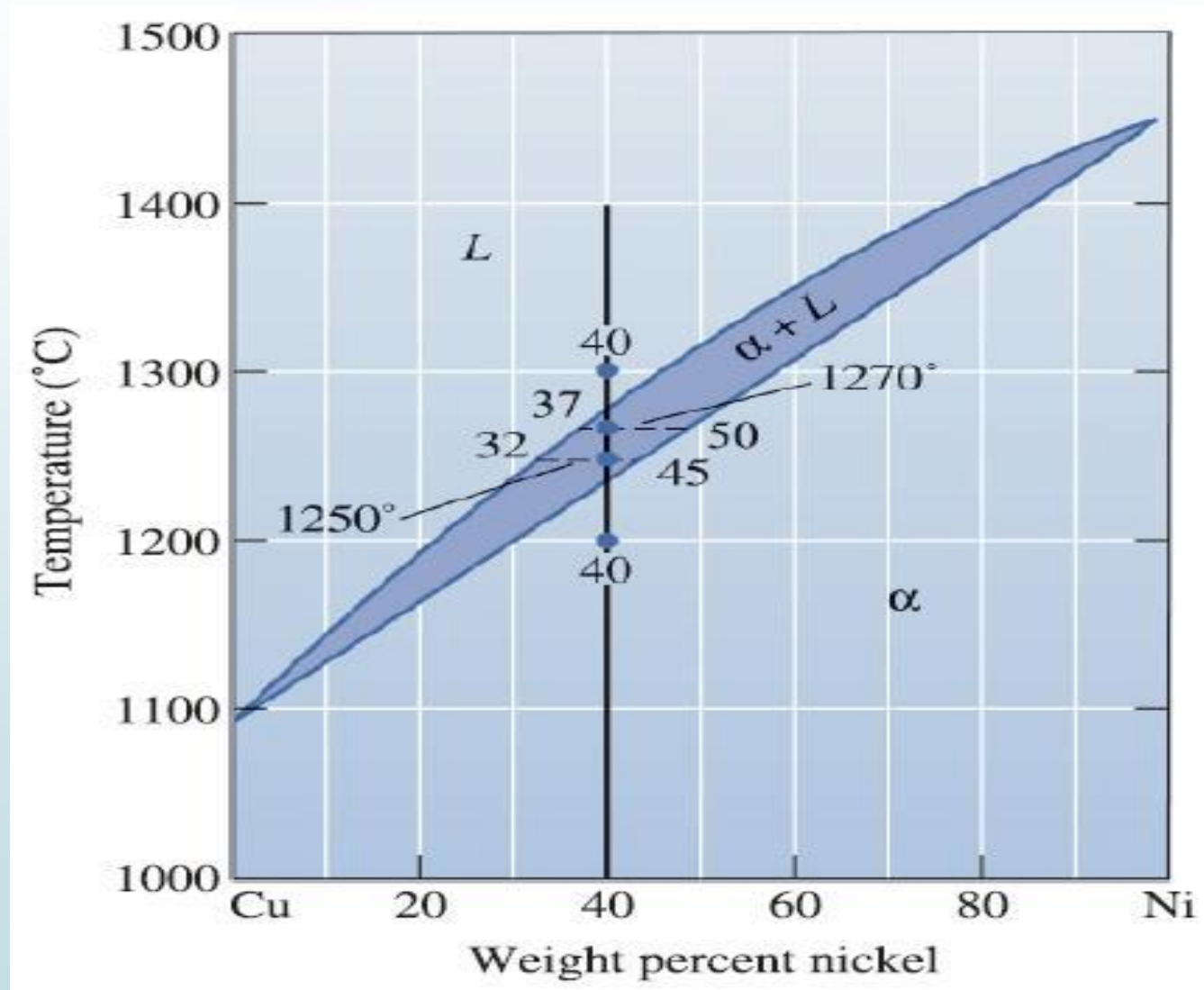
Development of microstructure in isomorphous alloys

Fast (non-equilibrium) cooling

Compositional changes require diffusion in solid and liquid phases

- Diffusion in the solid state is very slow. \Rightarrow The new layers that solidify on top of the existing grains have the equilibrium composition at that temperature but once they are solid their composition does not change. \Rightarrow Formation of layered (cored) grains and the invalidity of the tie-line method to determine the composition of the solid phase.
- The tie-line method still works for the liquid phase, where diffusion is fast. Average Ni content of solid grains is higher. \Rightarrow Application of the lever rule gives us a greater proportion of liquid phase as compared to the one for equilibrium cooling at the same T. \Rightarrow Solidus line is shifted to the right (higher Ni contents), solidification is complete at lower T, the outer part of the grains are richer in the low-melting component (Cu).
- Upon heating grain boundaries will melt first. This can lead to premature mechanical failure. 13

Determine the composition of each phase in a Cu-40% Ni alloy at 1300°C, 1270°C, 1250°C, and 1200°C.





The vertical line at 40% Ni represents the overall composition of the alloy.

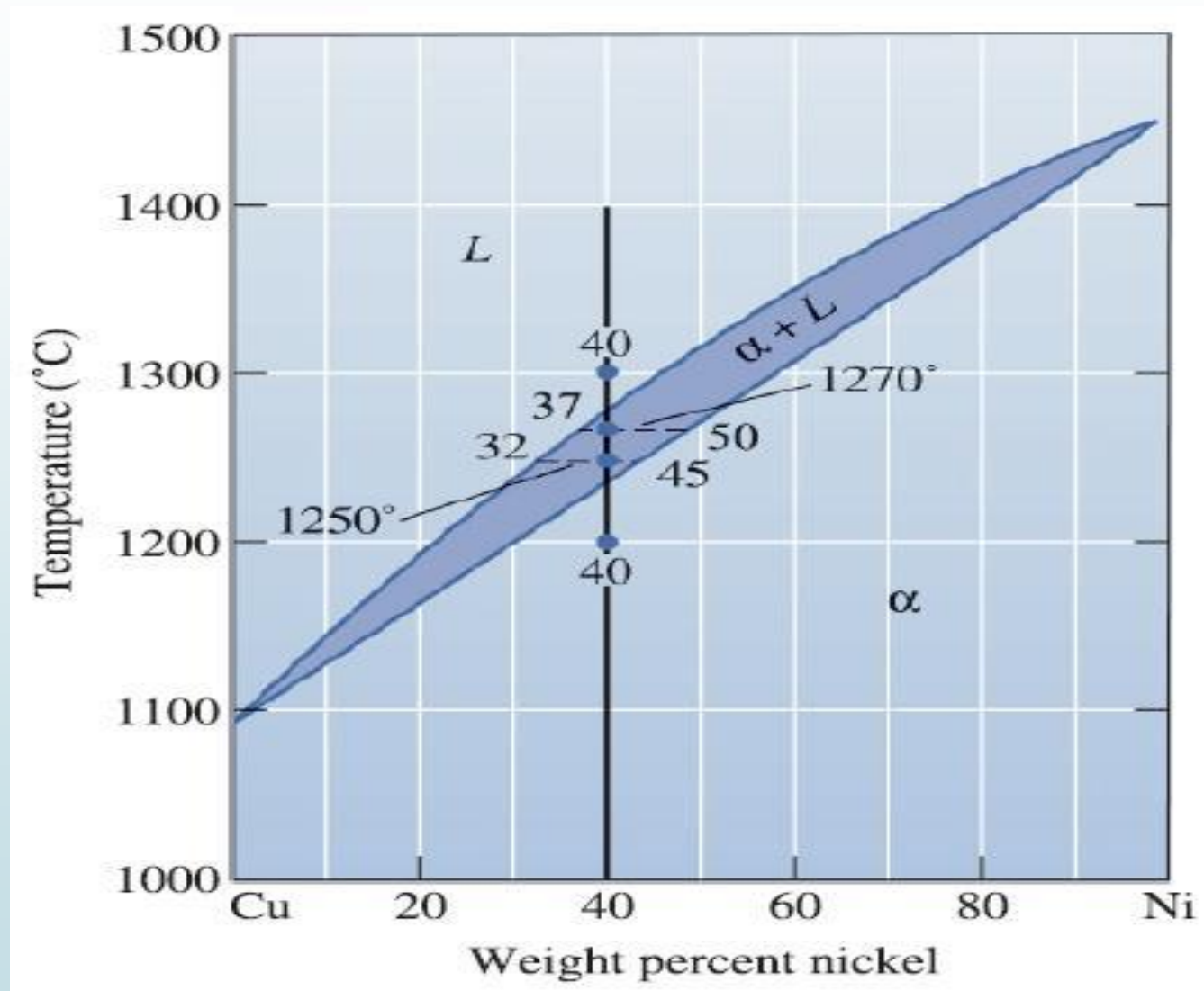
- **1300°C:** Only liquid is present. The liquid must contain 40% Ni, the overall composition of the alloy.

- **1270°C:** Two phases are present. A horizontal line within the $a+L$ field is drawn. The endpoint at the liquidus, which is in contact with the liquid region, is at 37% Ni. The endpoint at the solidus, which is in contact with the a region, is at 50% Ni. Therefore, the liquid contains 37% Ni, and the solid contains 50% Ni.

1250°C: Again two phases are present. The tie line drawn at this temperature show that the liquid contains 32% Ni, and the solid contains 45% Ni.

- **1200°C:** Only solid a is present, so the solid must contain 40% Ni.

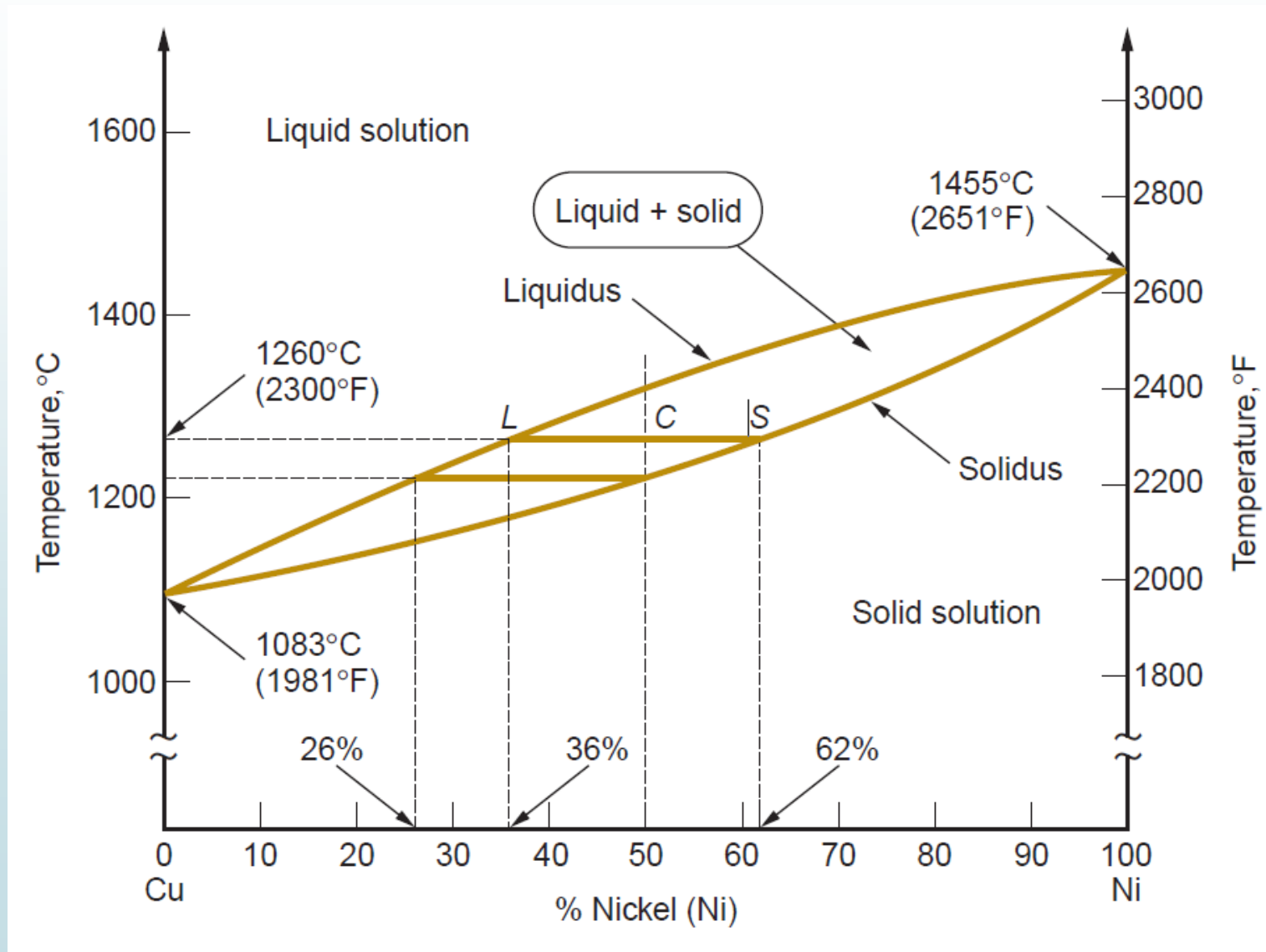
Determine the amount of each phase in the Cu-40% Ni alloy shown in Figure at 1300°C, 1270°C, 1250°C, and 1200°C




Determine the amount of each phase in the Cu-40% Ni alloy shown in Figure 6-10 at 1300°C, 1270°C, 1250°C, and 1200°C

- **1300°C:** There is only one phase, so 100% L .
- **1270°C:** $\% L = \frac{50 - 40}{50 - 37} \times 100 = 77\%$
 $\% \alpha = \frac{40 - 37}{50 - 37} \times 100 = 23\%$
- **1250°C:** $\% L = \frac{45 - 40}{45 - 32} \times 100 = 38\%$
 $\% \alpha = \frac{40 - 32}{45 - 32} \times 100 = 62\%$
- **1200°C:** There is only one phase, so 100% α .

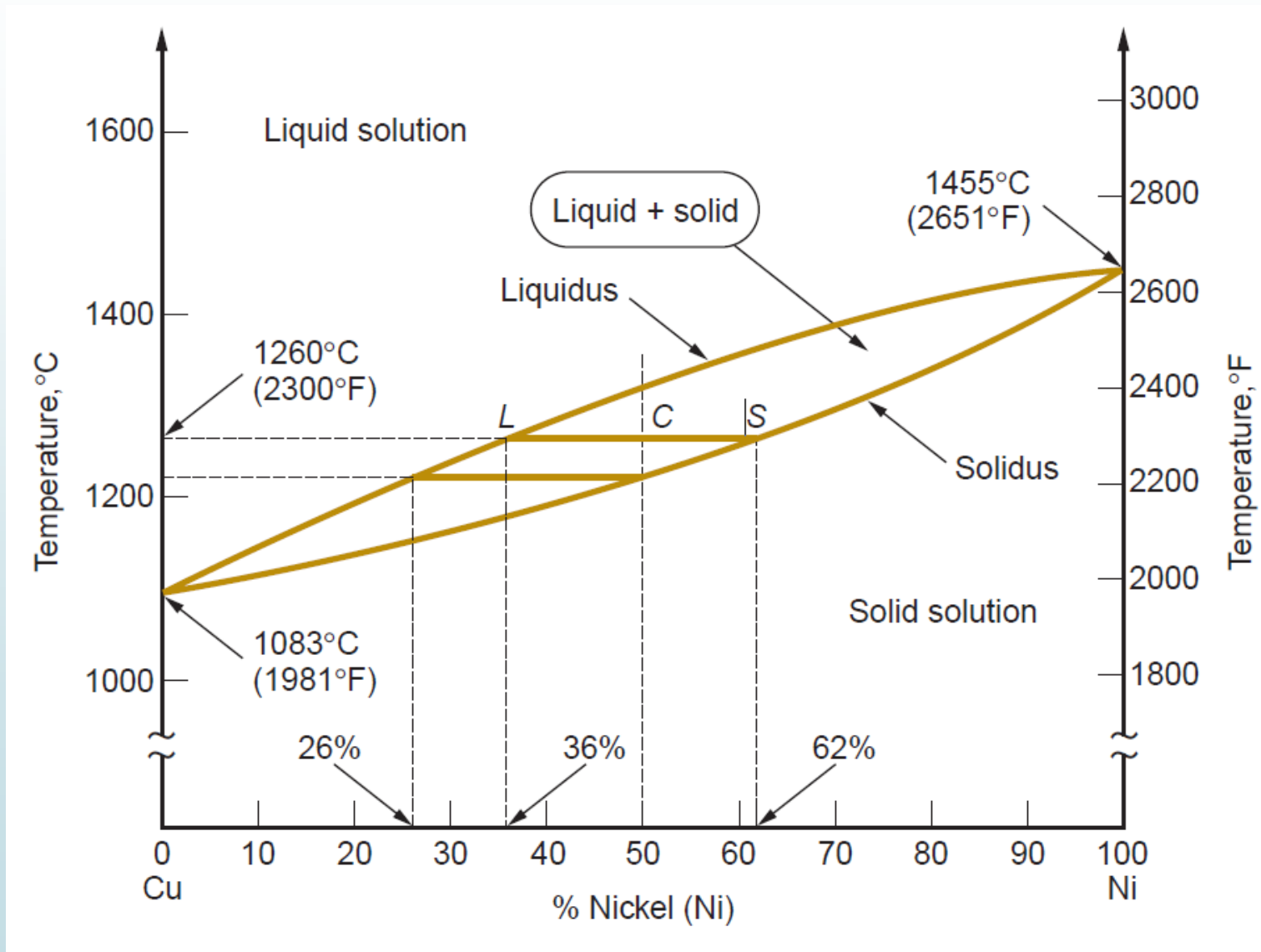
Analyze the compositions of the liquid and solid phases present in the copper nickel system at an aggregate composition of 50% nickel and a temperature of 1260°C.





Solution: A horizontal line is drawn at the given temperature level as shown in Figure . The line intersects the solidus at a composition of 62% nickel, thus indicating the composition of the solid phase. The intersection with the liquidus occurs at a composition of 36% Ni, corresponding to the analysis of the liquid phase.

H. W. Determine the proportions of liquid and solid phases for the 50% nickel composition of the copper–nickel system at the temperature of 1260°C



Liquid

Freezing

Solid



Nuclei of crystallization

Grain

Grain boundary

Thank you for listening