

ALEACIONES BINARIAS

Julio Alberto Aguilar Schafer

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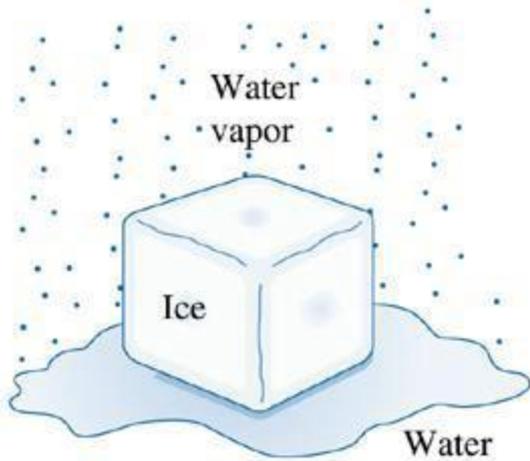
Homogeneas:

- Solución sólida (SS):
ej. Latones α
- Compuesto químico definido (CQD):
ej. Cementita (Fe_3C)

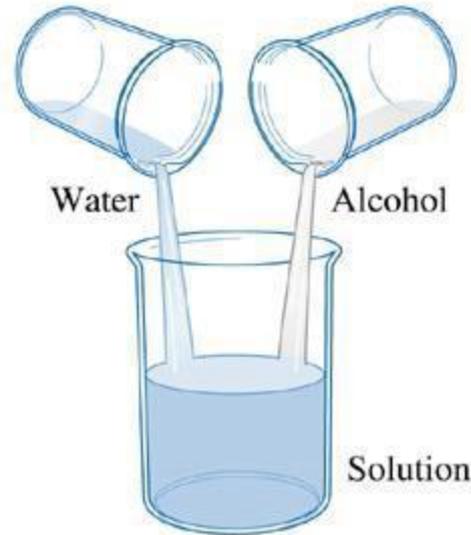
Heterogeneas:

- SS + SS:
el. Latones $\alpha+\beta$
- SS + CQD:
el. Perlita ($\text{Fe}+\text{Fe}_3\text{C}$)
- CQD + CQD:

fases



(a)

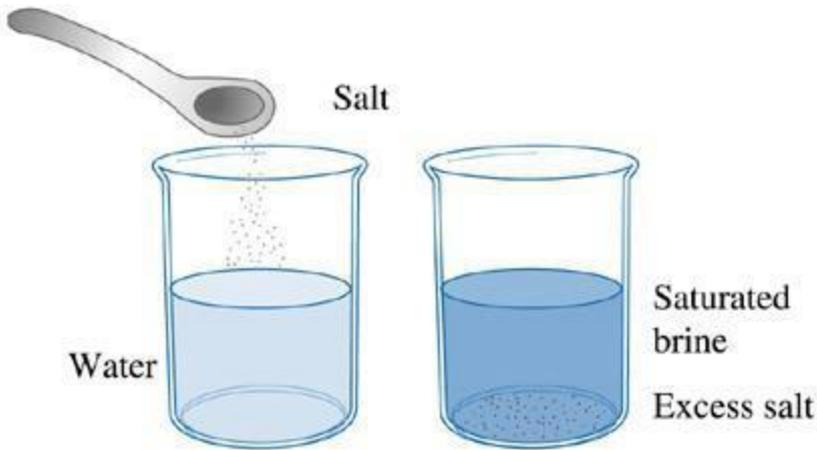


(b)

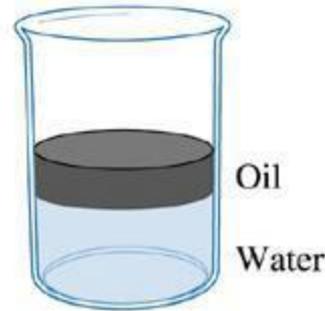
a y b) Solubilidad ilimitada

c) Agua y sal solubilidad limitada

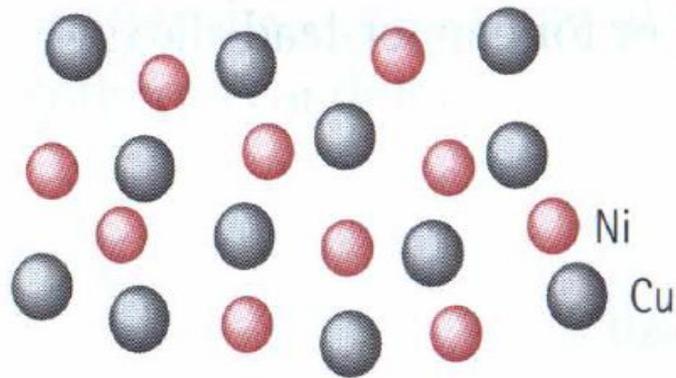
d) Aceite y agua prácticamente insolubles



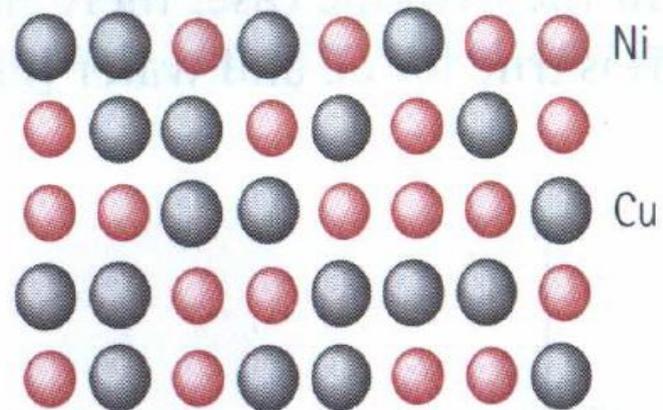
(c)



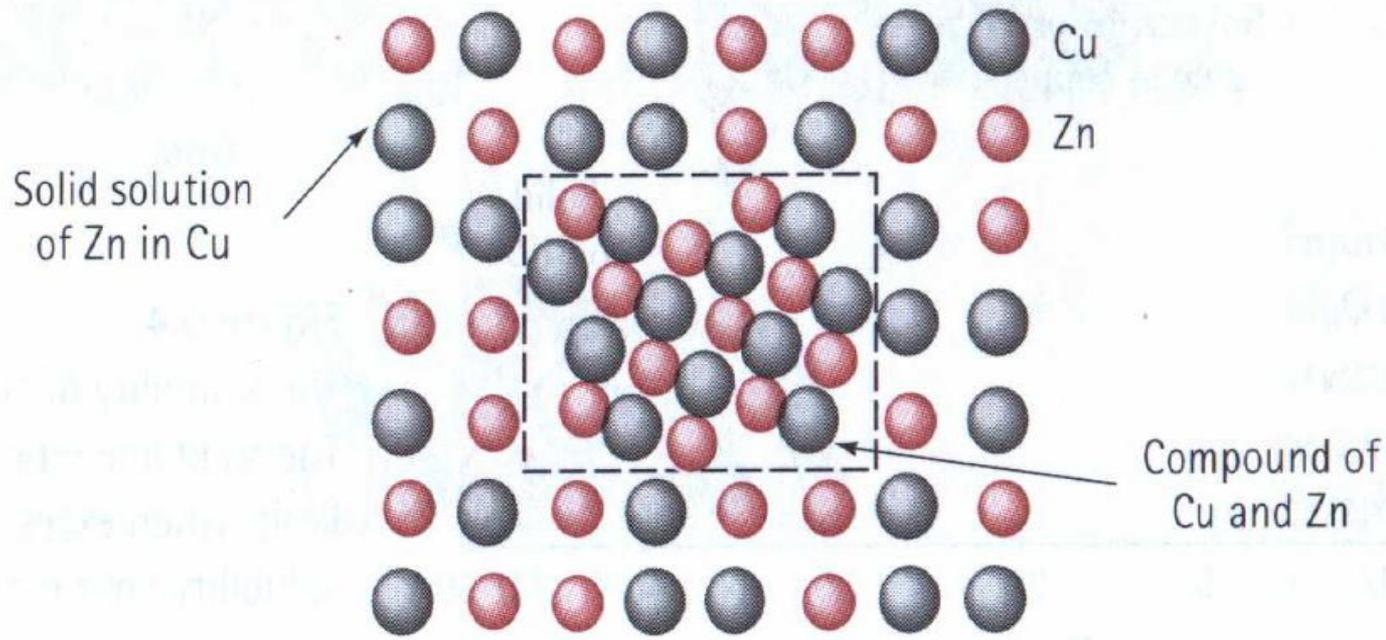
(d)



(a)

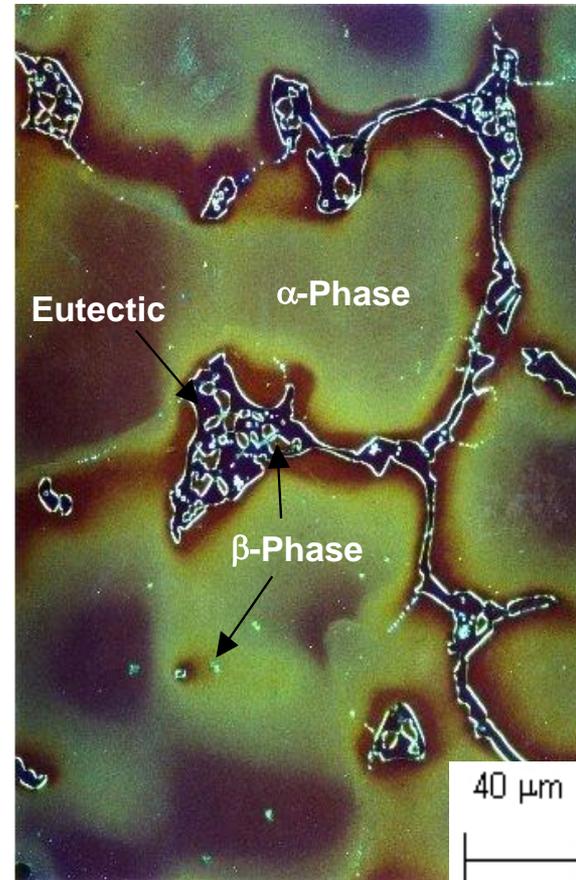
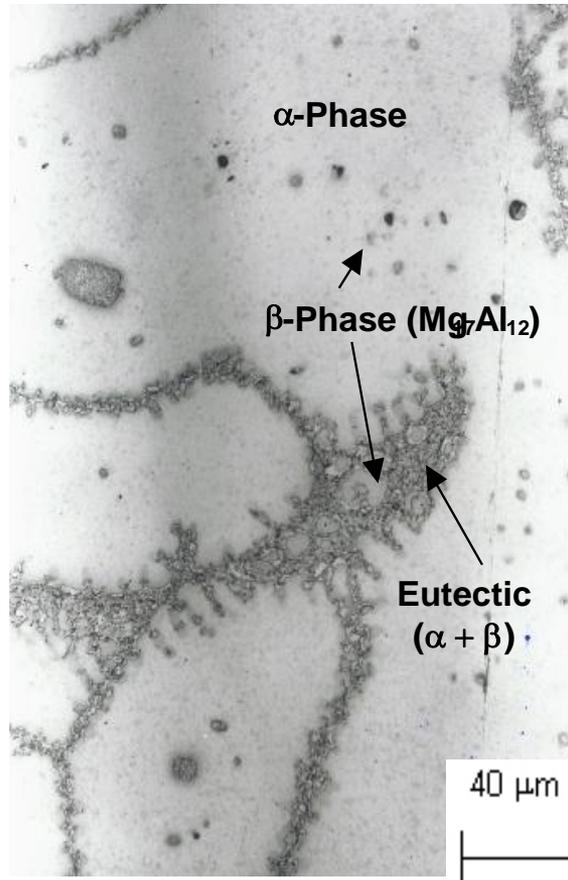


(b)



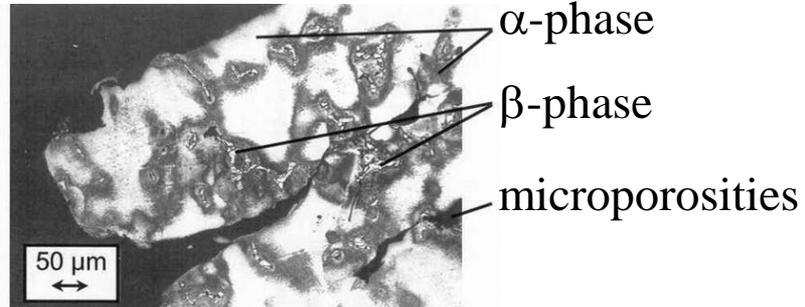
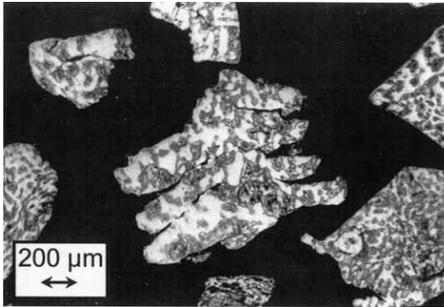
(c)

alloy AZ91 (MgAl9Zn1), RSCT thixo pre-material

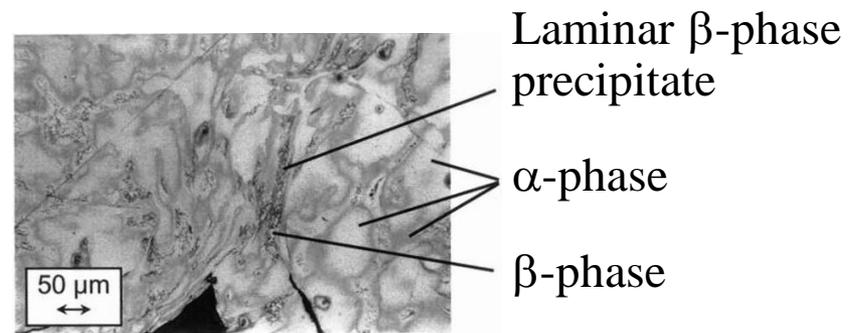
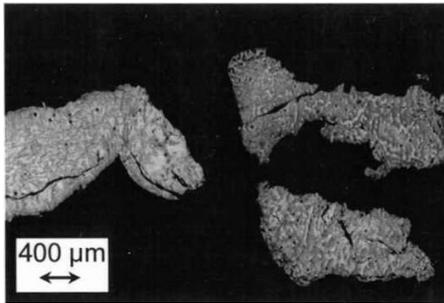


RSCT: microstructure composition

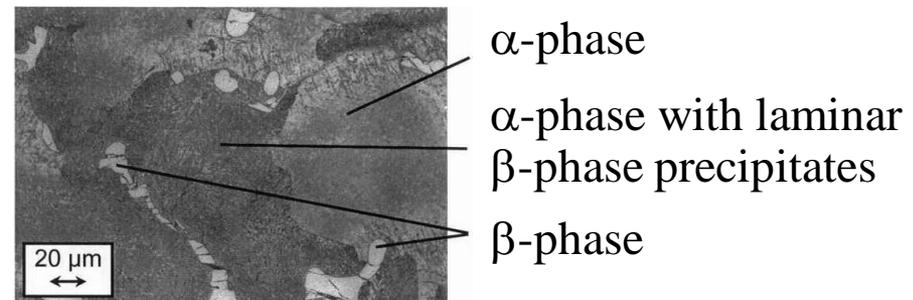
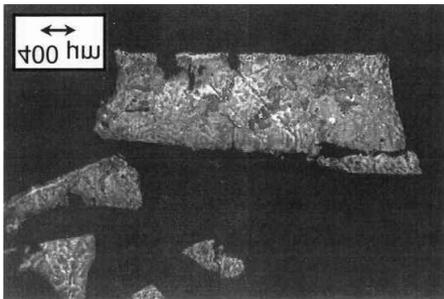
A



B

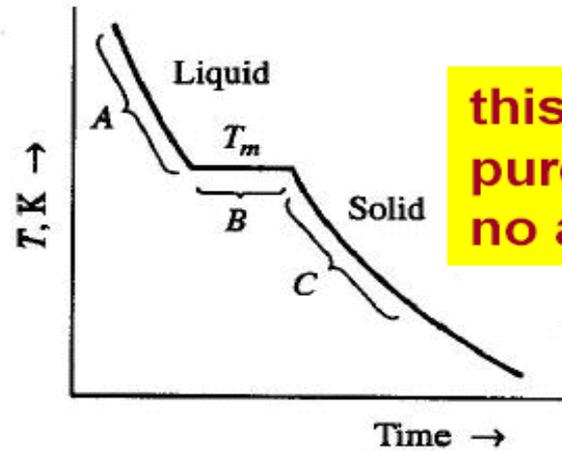
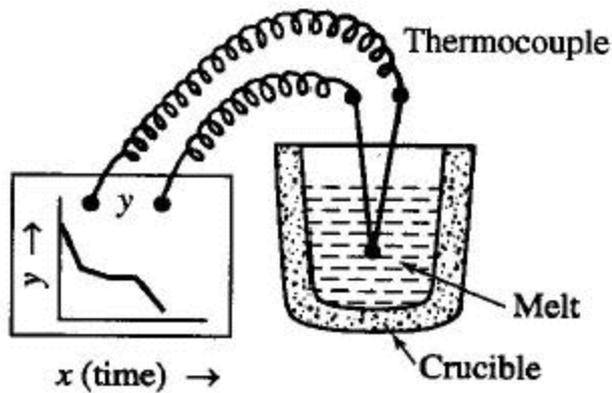


C

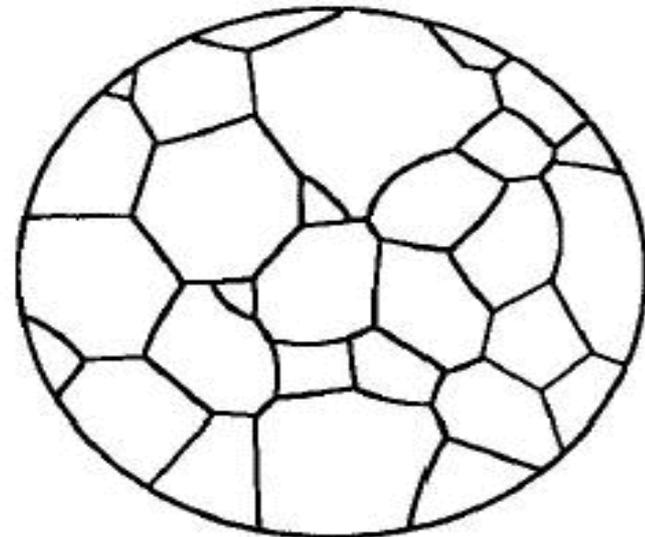


Análisis de microestructura

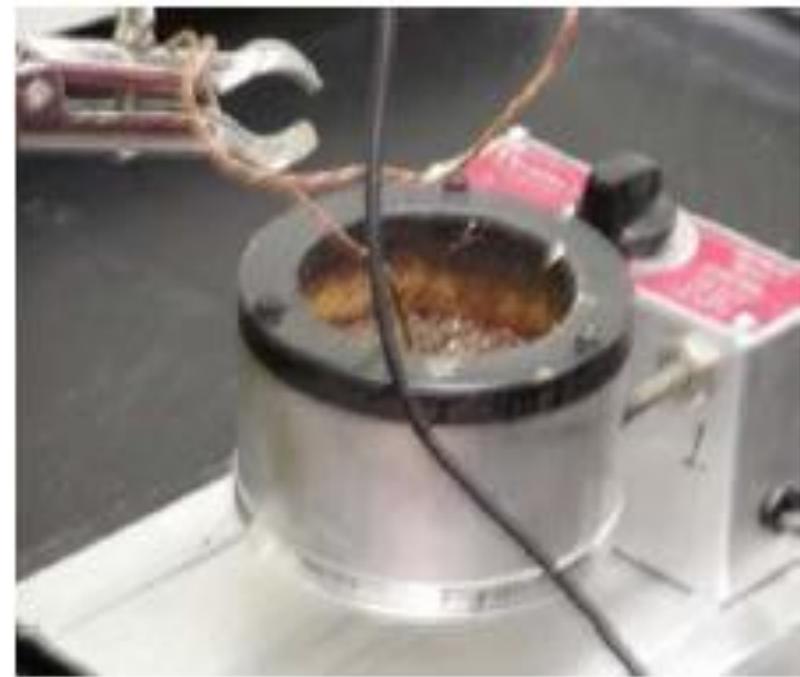
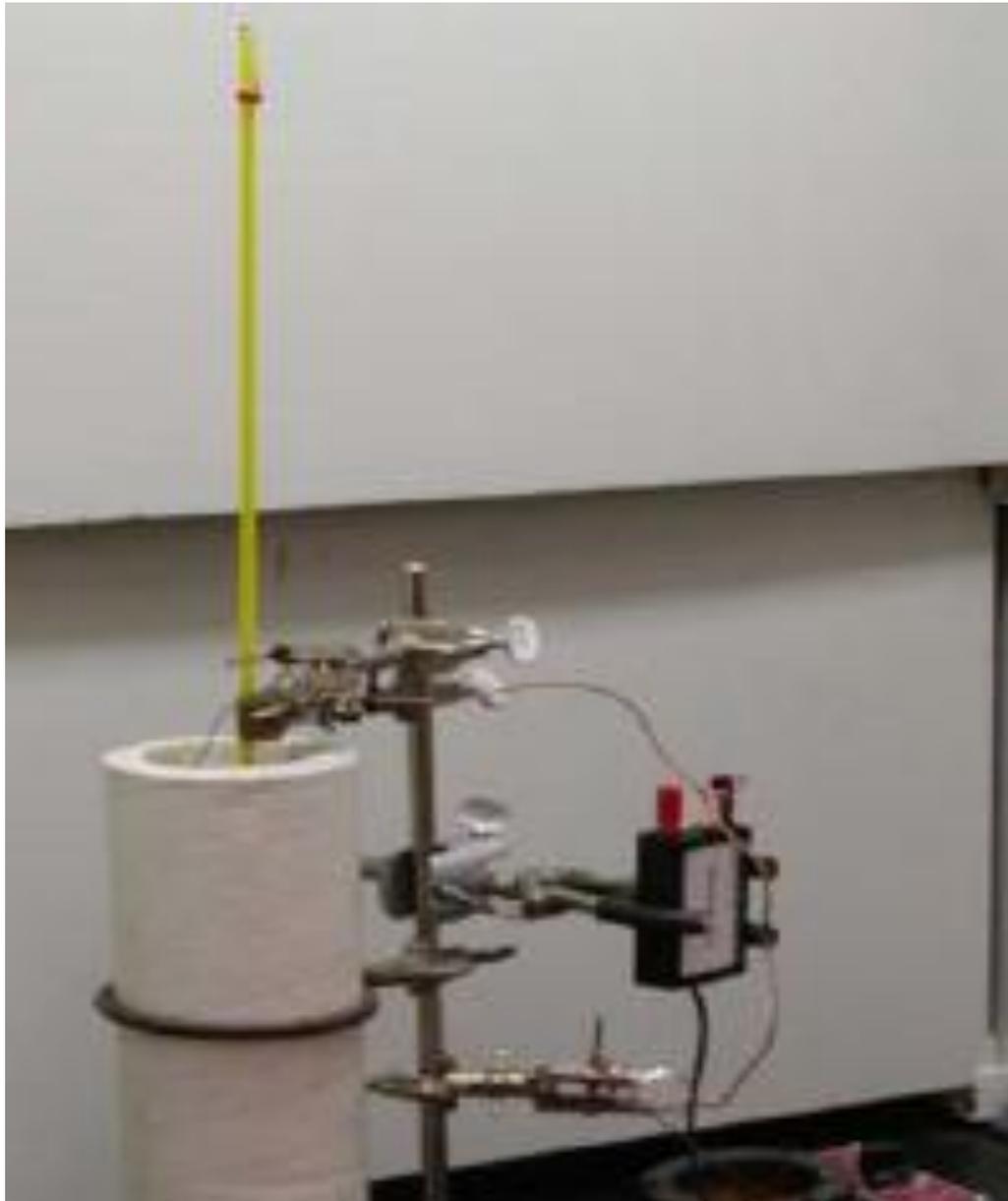
Solidificación de un metal puro



this is for a pure metal, no alloying



EQUIPO DE LABORATORIO PARA ANÁLISIS TÉRMICOS



Estados alotrópicos del Hierro

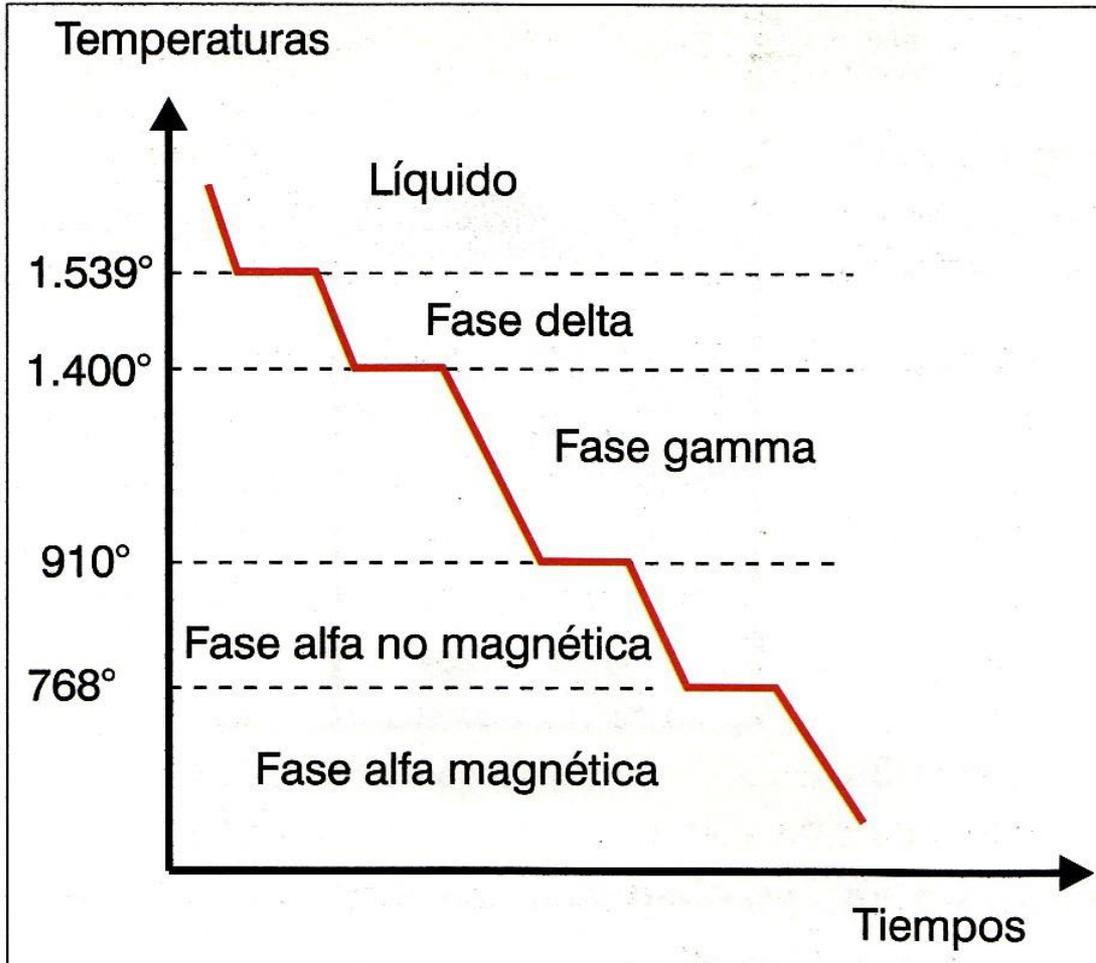


Figura 2.8. Diagrama de estados alotrópicos del hierro.

- Fase líquida ($>1539^{\circ}\text{C}$)
- $\text{Fe}\delta \rightarrow (\text{BCC})$
- $\text{Fe}\gamma \rightarrow (\text{FCC})$
- $\text{Fe}\beta \rightarrow (\text{BCC})$
- $\text{Fe}\alpha \rightarrow (\text{BCC})$

Estados alotrópicos

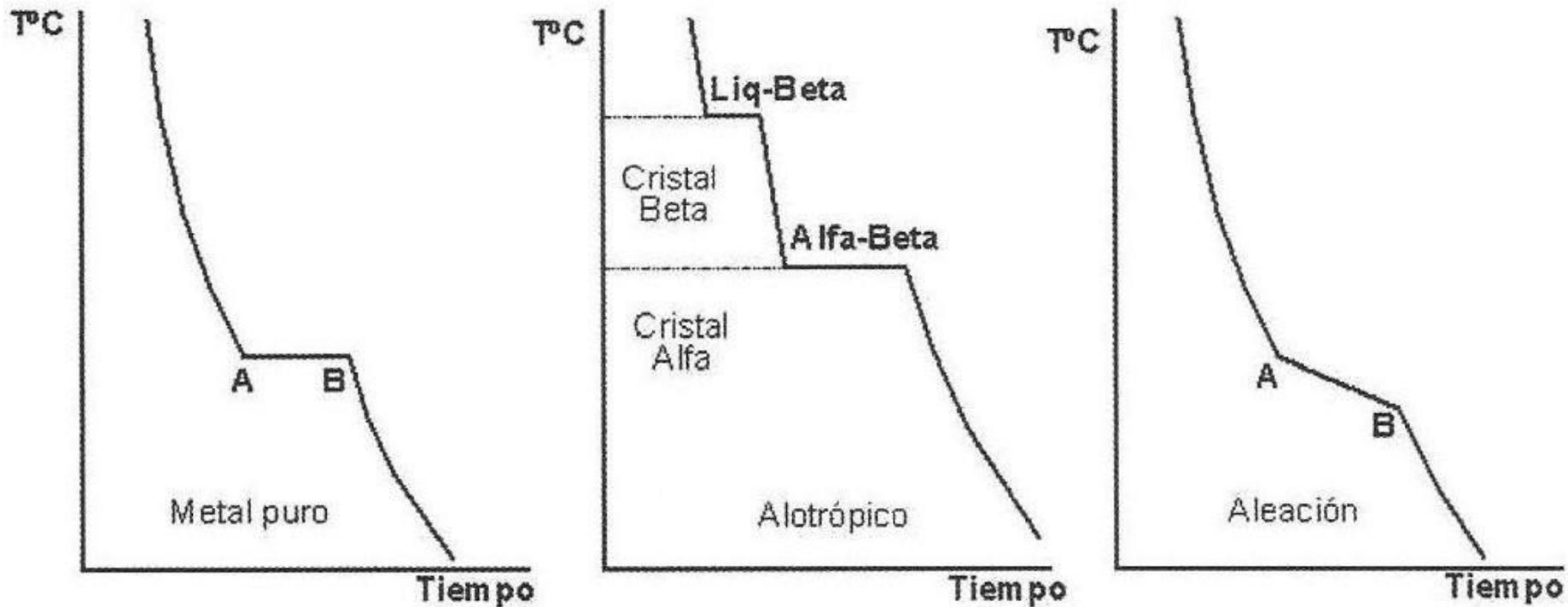


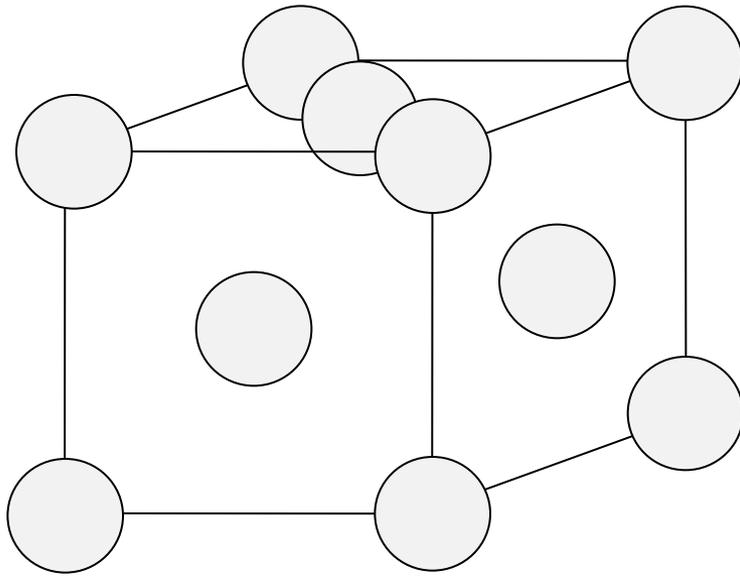
Figura 3.7. Curvas de enfriamiento para un metal puro, metal con transformación alotrópica y una aleación

- Un **diagrama de fases** muestra las fases y sus composiciones en cualquier combinación de temperatura y composición de la aleación.
- **Se tienen 3 tipos de diagramas:**
 - **Tipo I:** Solubilidad total al estado sólido y líquido
 - **Tipo II:** Solubilidad total al estado líquido e insolubilidad al estado sólido
 - **Tipo III:** Solubilidad total al estado líquido y solubilidad parcial al estado sólido.

Un diagrama de equilibrio o más comúnmente llamado diagrama de fases es un diagrama Temperatura vs. Composición el cual muestra las fases presentes en condiciones de equilibrio.

Sistemas binarios característicos

- Solubles en estado líquido y en estado sólido
- Solubles en estado líquido e insolubles en estado sólido
- Solubles en estado líquido y parcialmente solubles en estado sólido
- Sistemas que forman compuestos intermetálicos

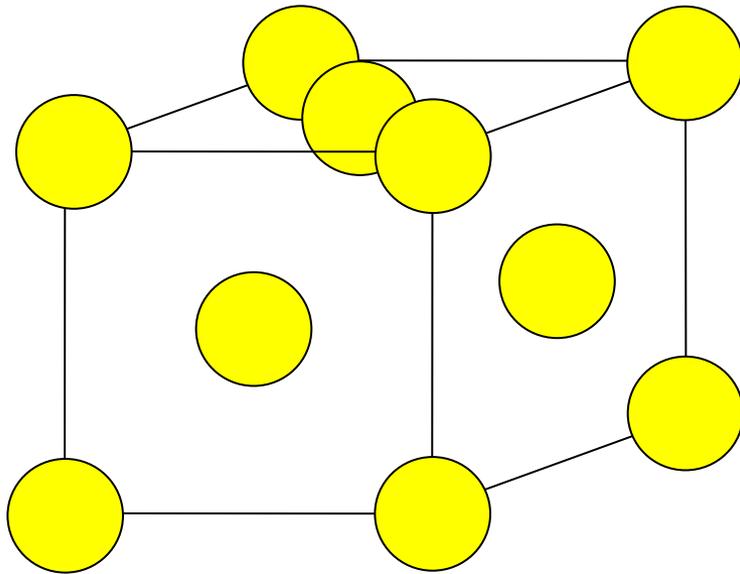


Ag

Estructura FCC

Temp fusión= 960°C

R at.= 1.65Å

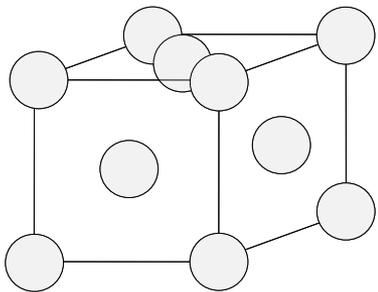
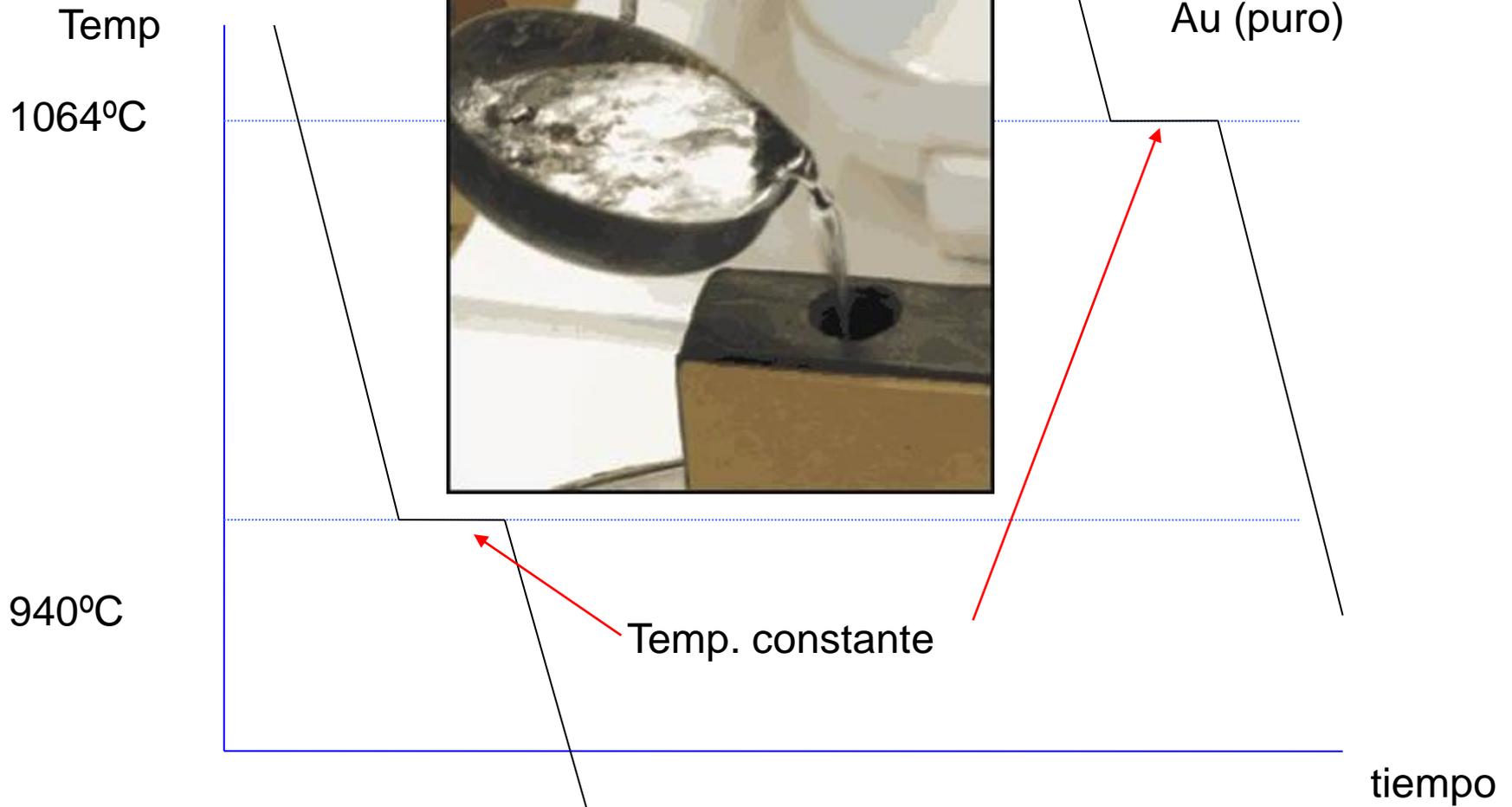


Au

Estructura FCC

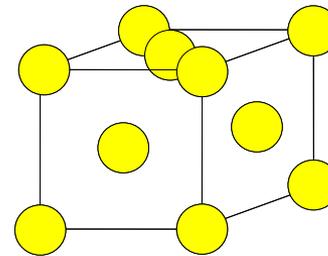
Temp fusión= 1064°C

R at.= 1.74Å

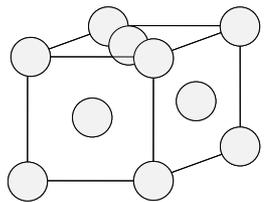
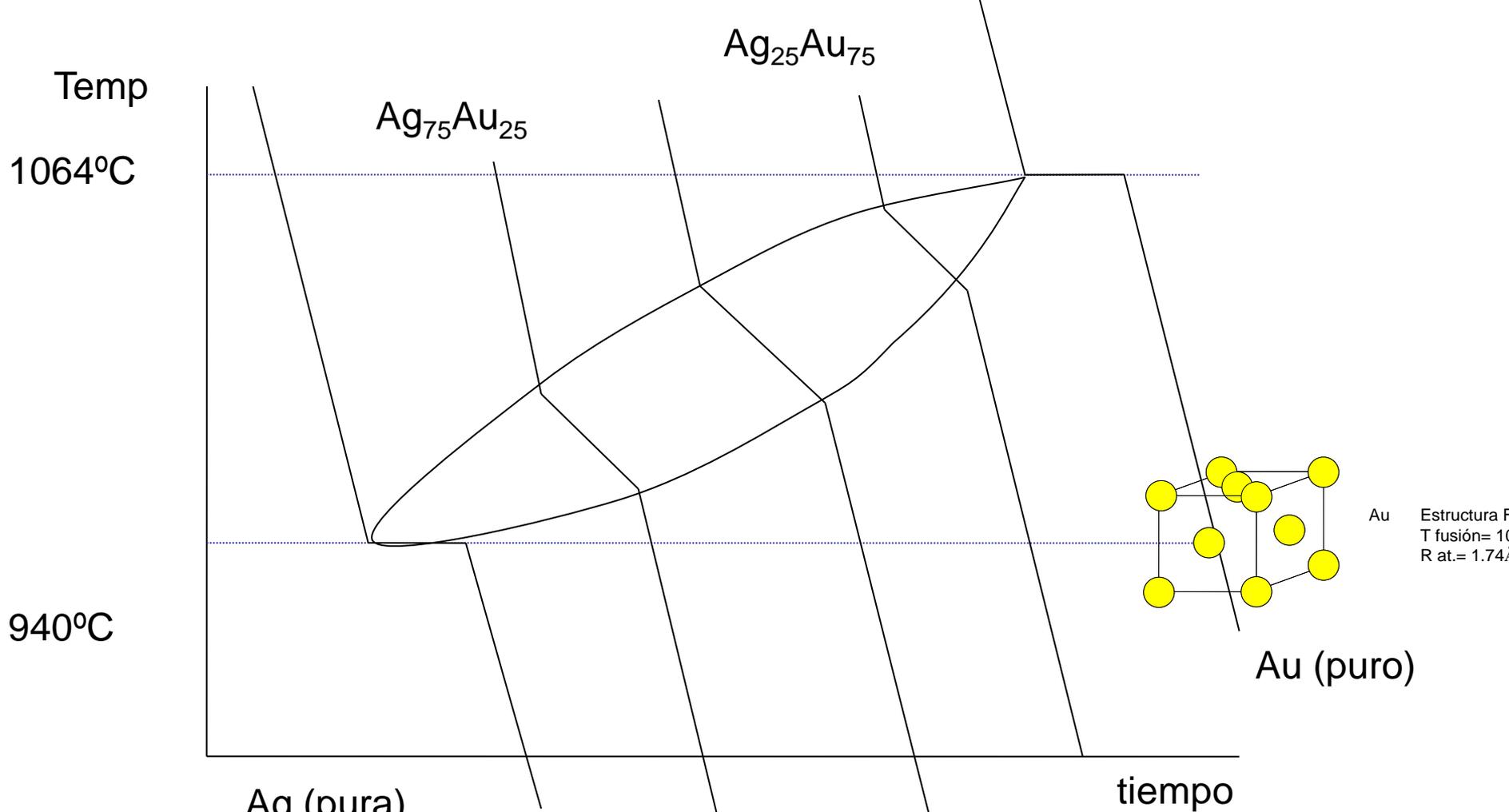


Ag (pura)

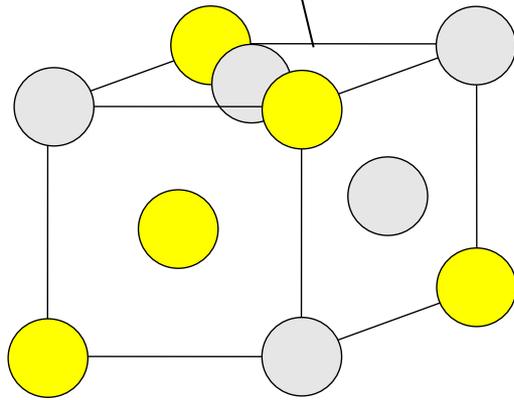
Ag Estructura FCC
 T fusión= 960
 R at.= 1.65Å



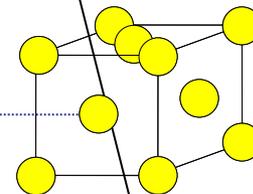
Au Estructura FCC
 T fusión= 1064
 R at.= 1.74Å



Ag Estructura FCC
T fusión= 960
R at.= 1.65Å

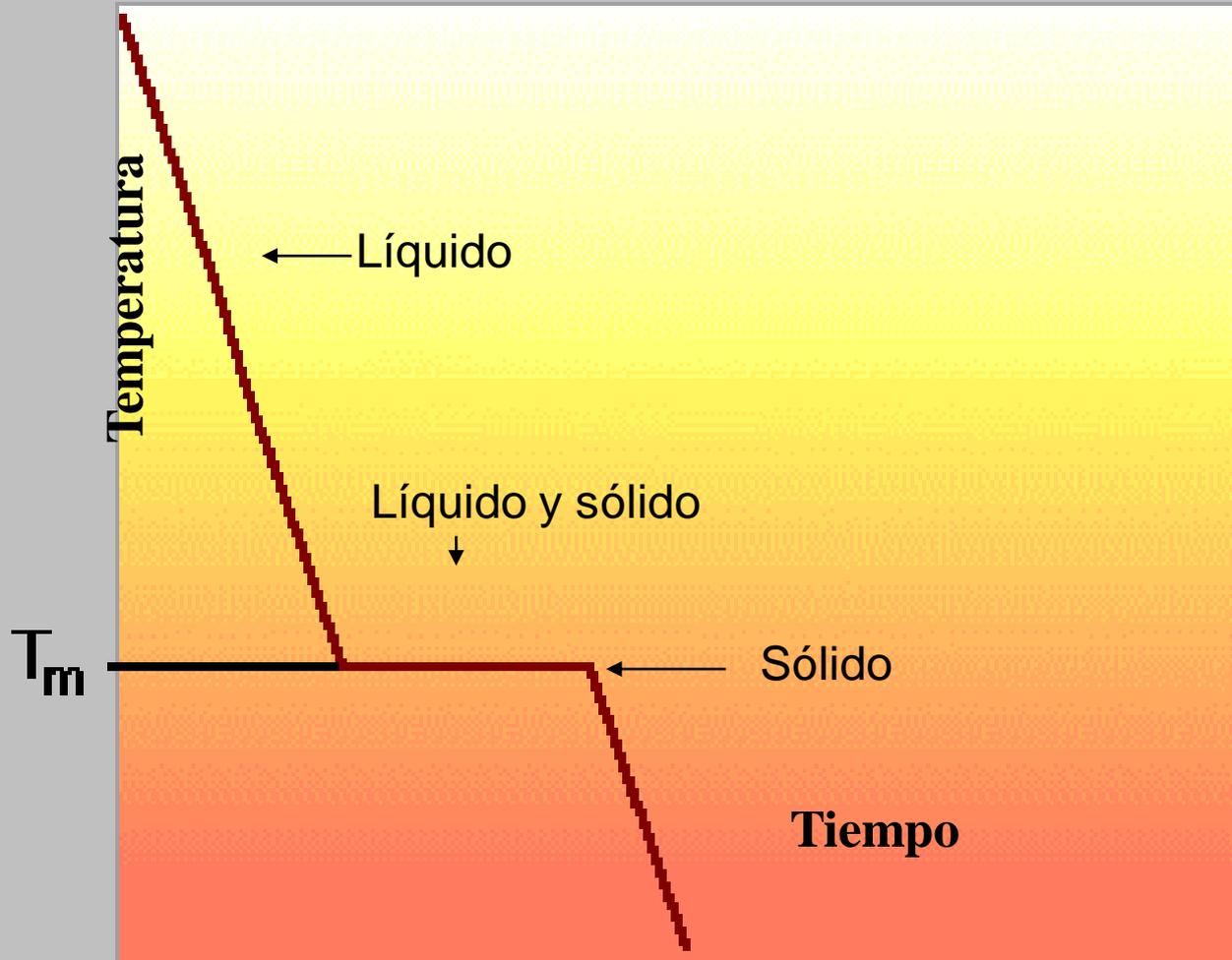


Ag₅₀Au₅₀
50% y 50%
(AgAu)



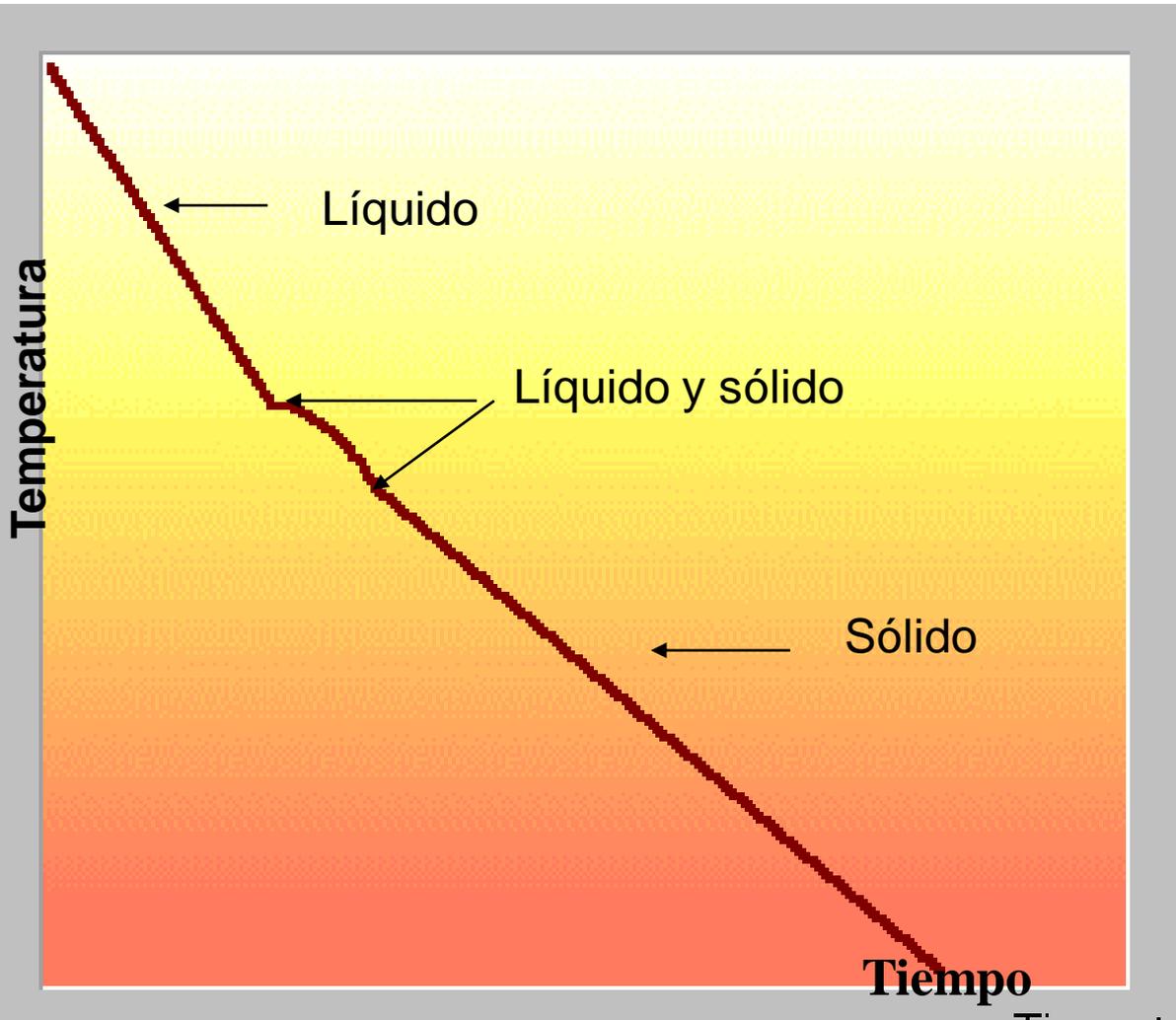
Au Estructura FCC
T fusión= 1063
R at.= 1.74Å

Curva de enfriamiento de un elemento puro en función del tiempo



Cuando comienza a solidificar la temperatura se mantiene constante.

Curva de enfriamiento para una sustancia que posee dos componentes o elementos y una dada composición



A diferencia del caso anterior el líquido y el sólido coexisten no solo a una temperatura sino que a un rango

Curva de enfriamiento para una sustancia que posee dos componentes o elementos para diferentes composiciones el elemento puro A tiene menor temperatura de fusión que el elemento B

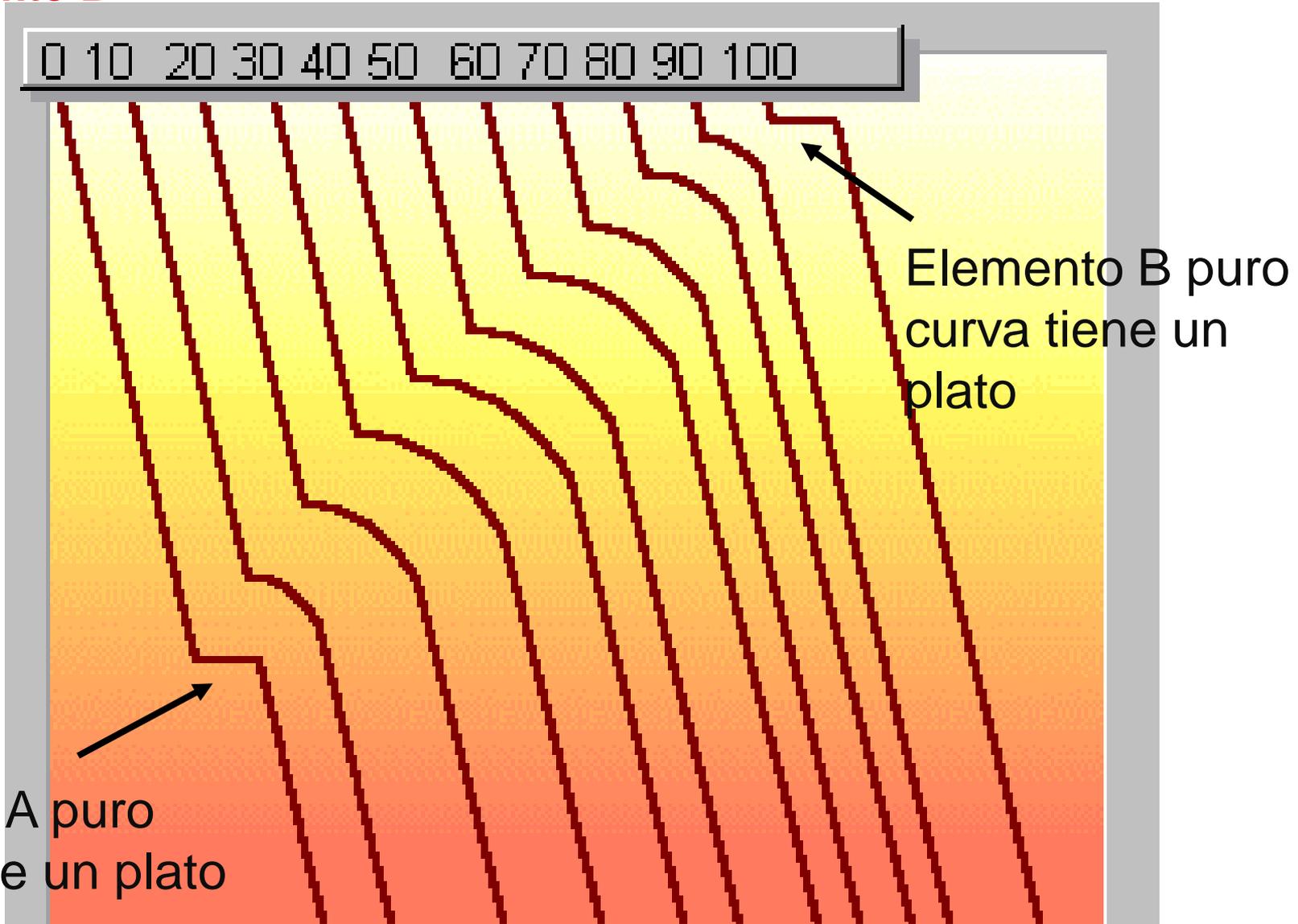
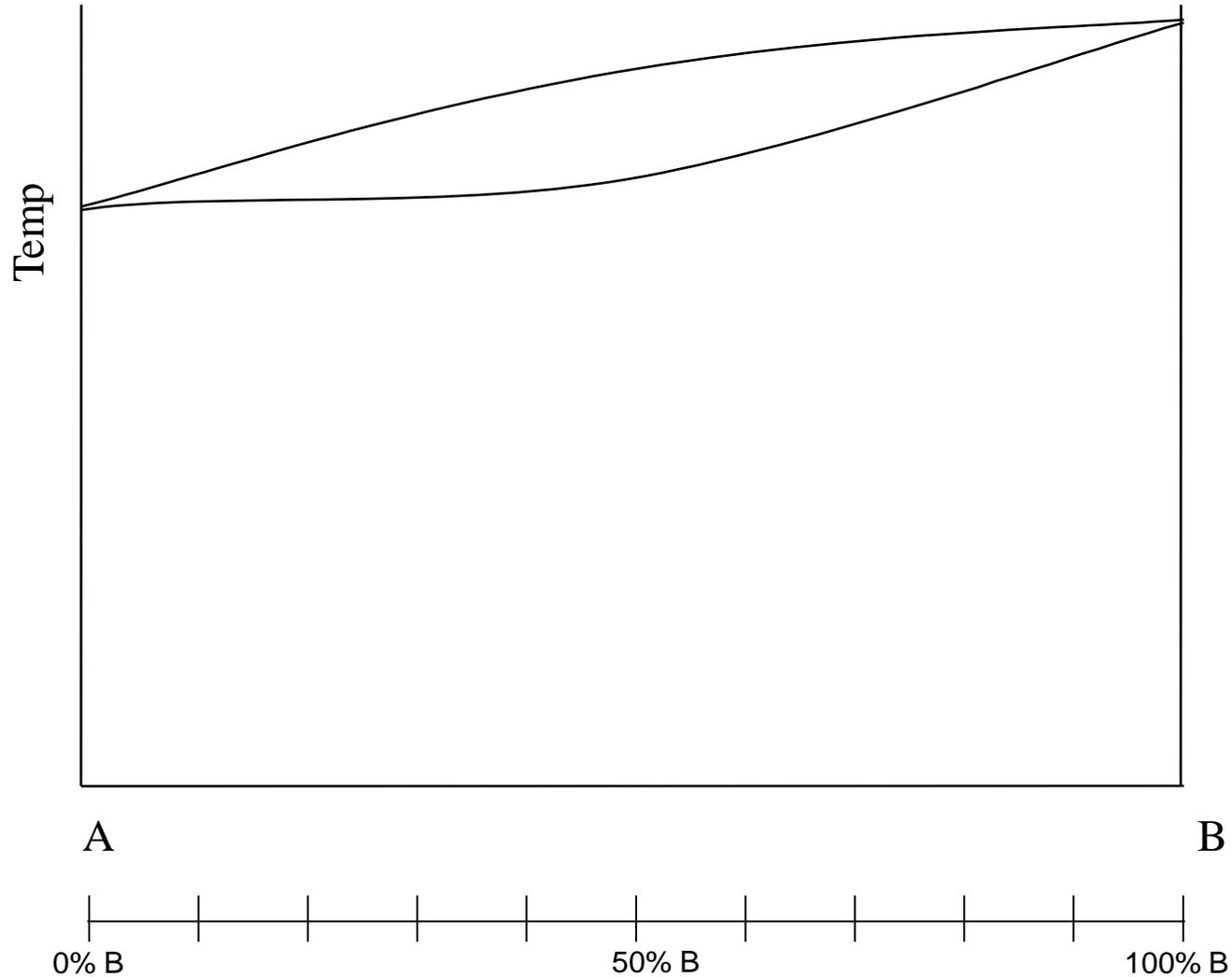
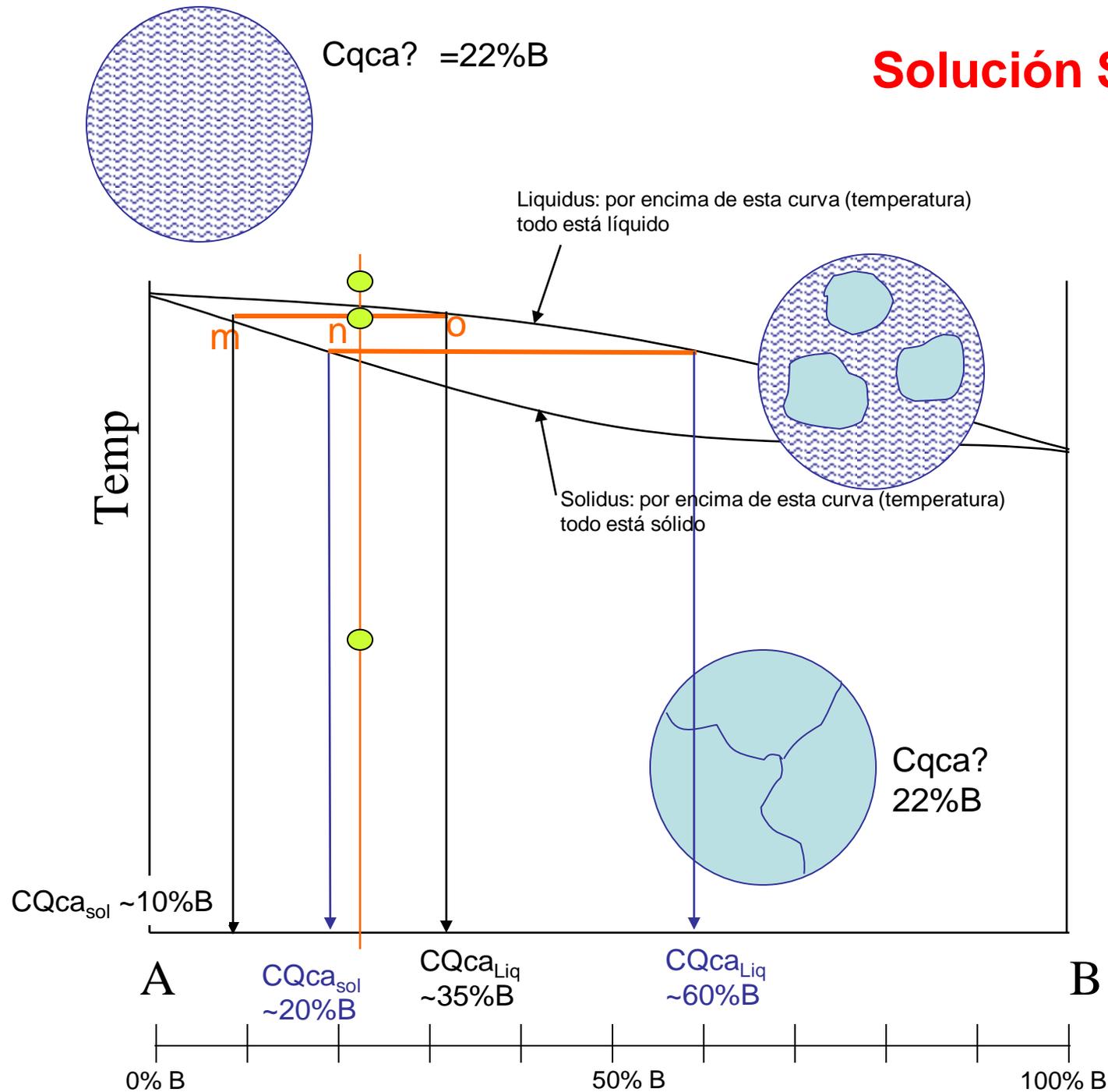
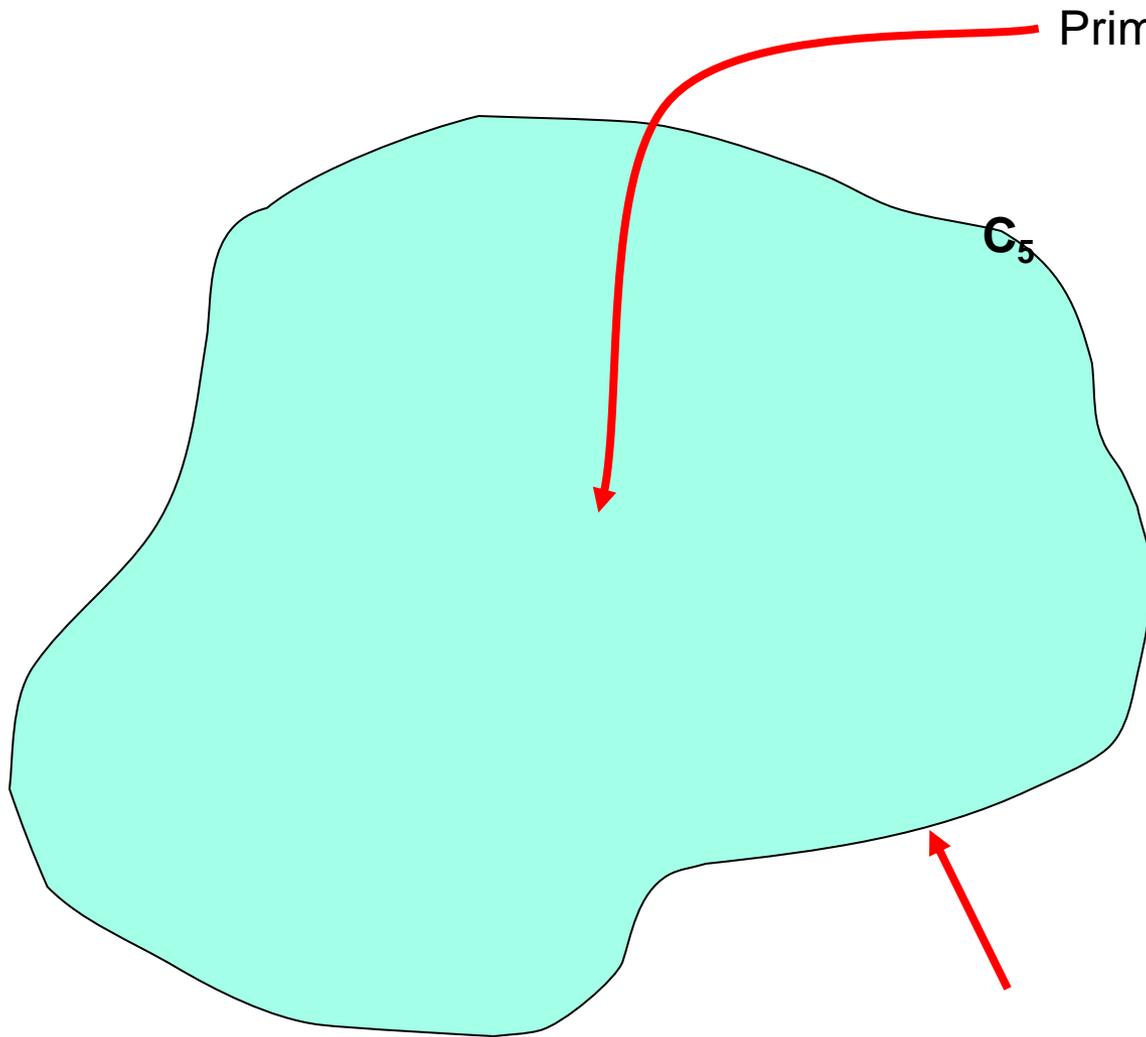


Diagrama Temperatura-Composición

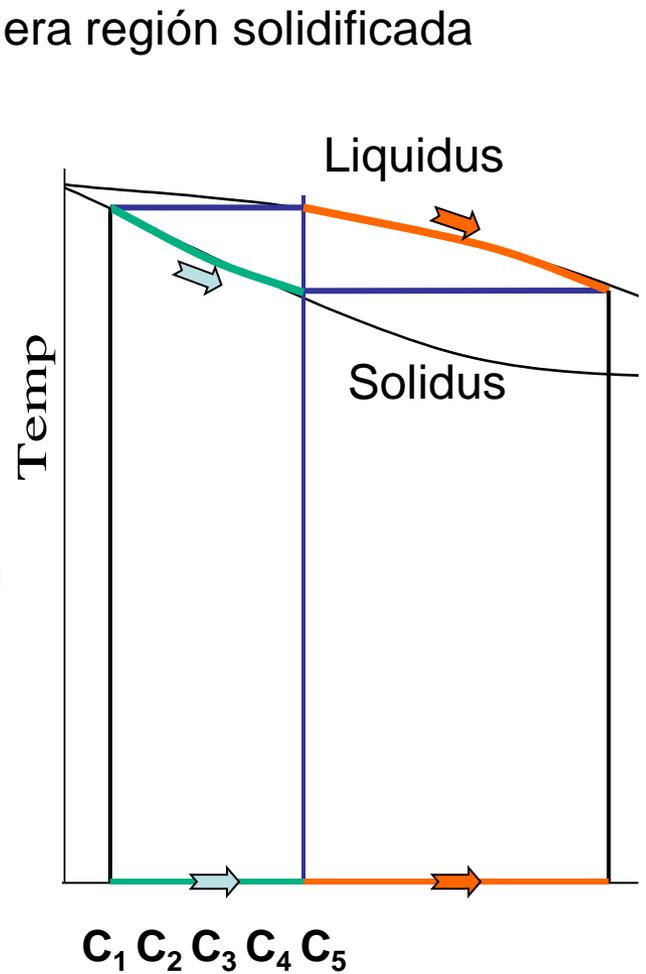


Solución Sólida

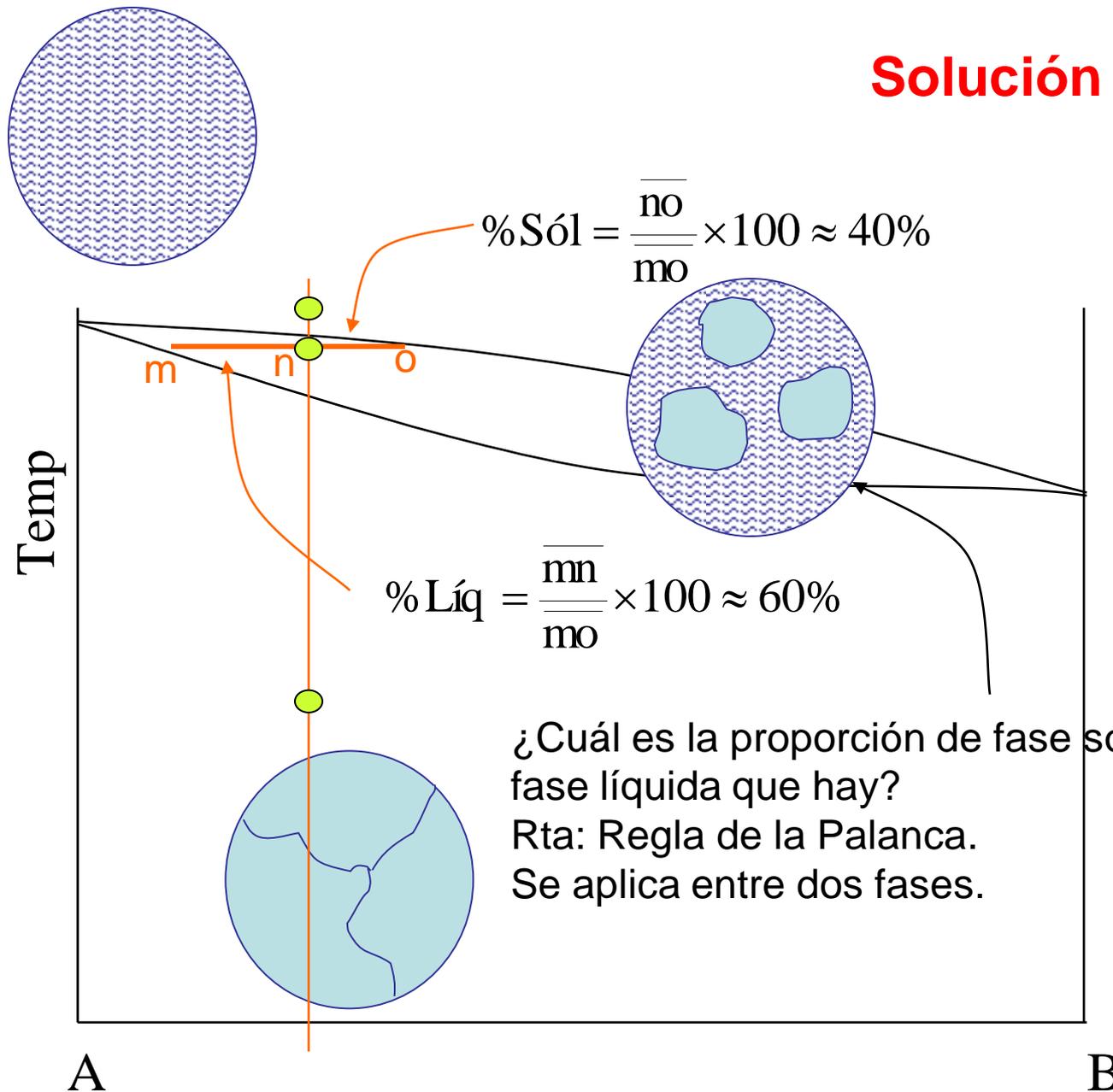




Borde de grano.
Última región solidificada



Solución Sólida



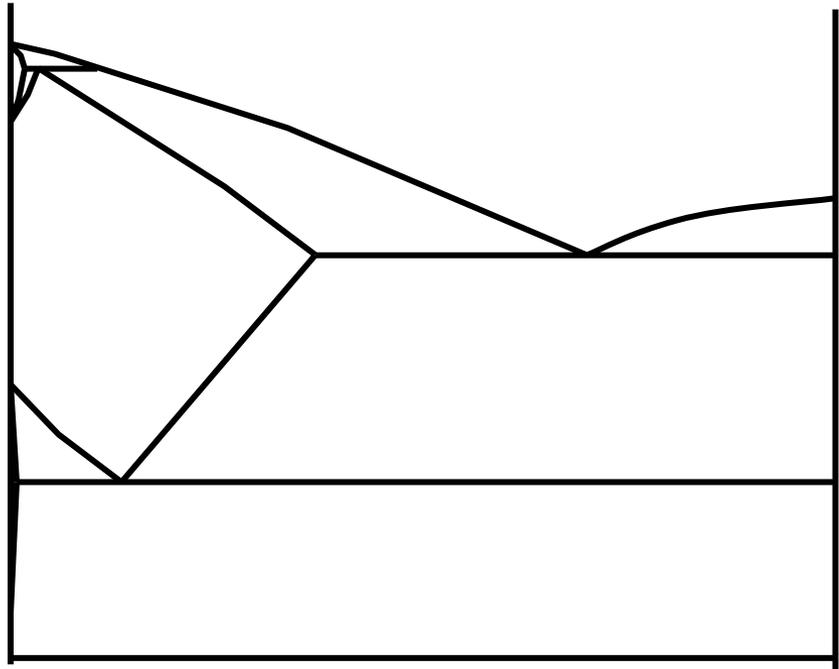
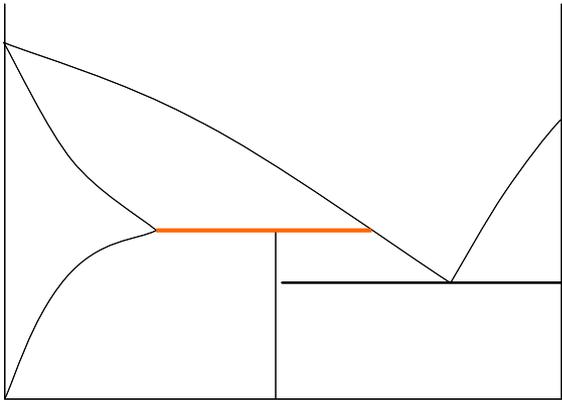
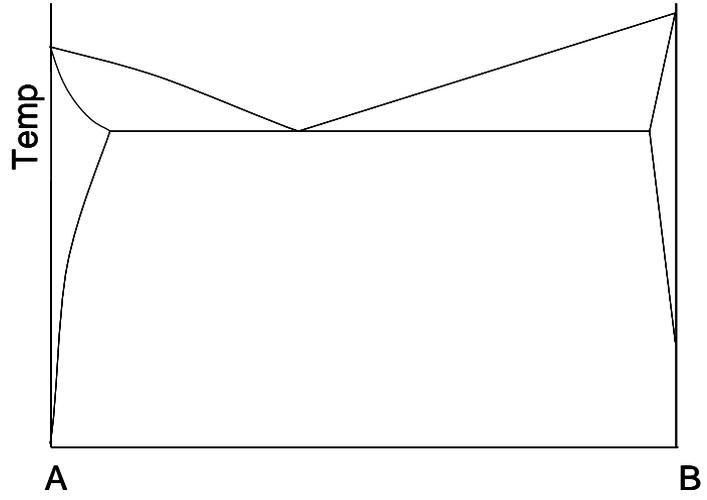
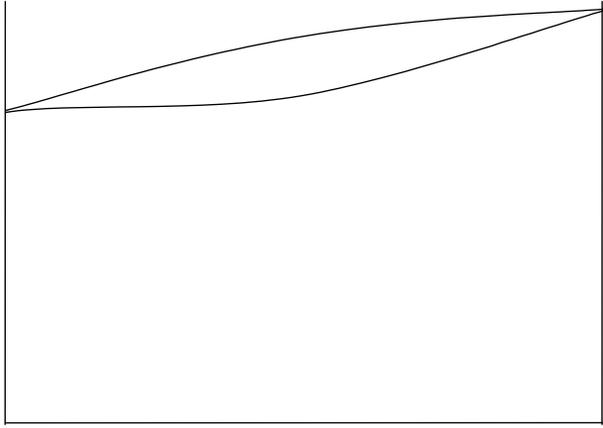
REGLAS DE HUME-ROTHERY

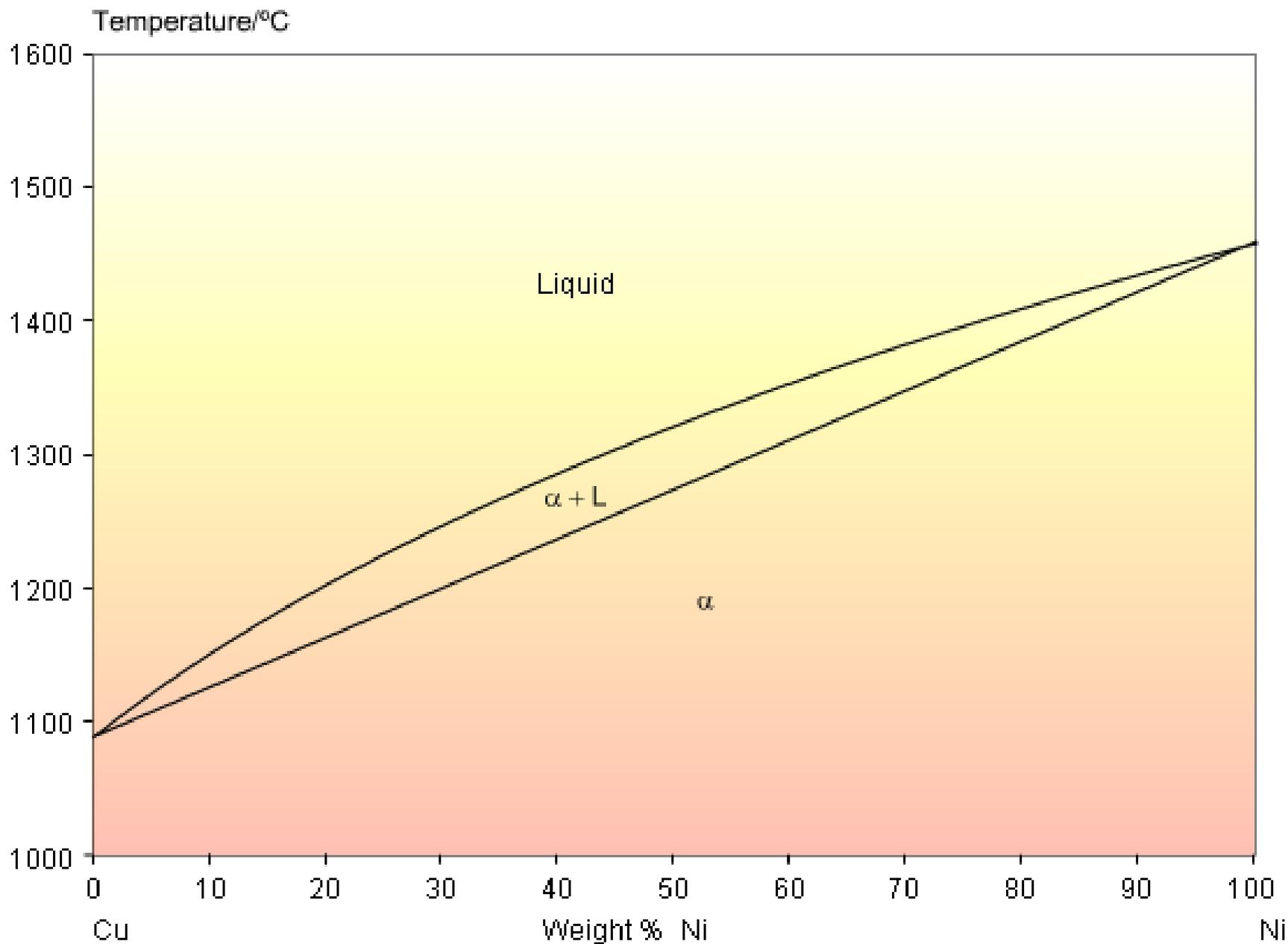
Para obtener una solución sólida total

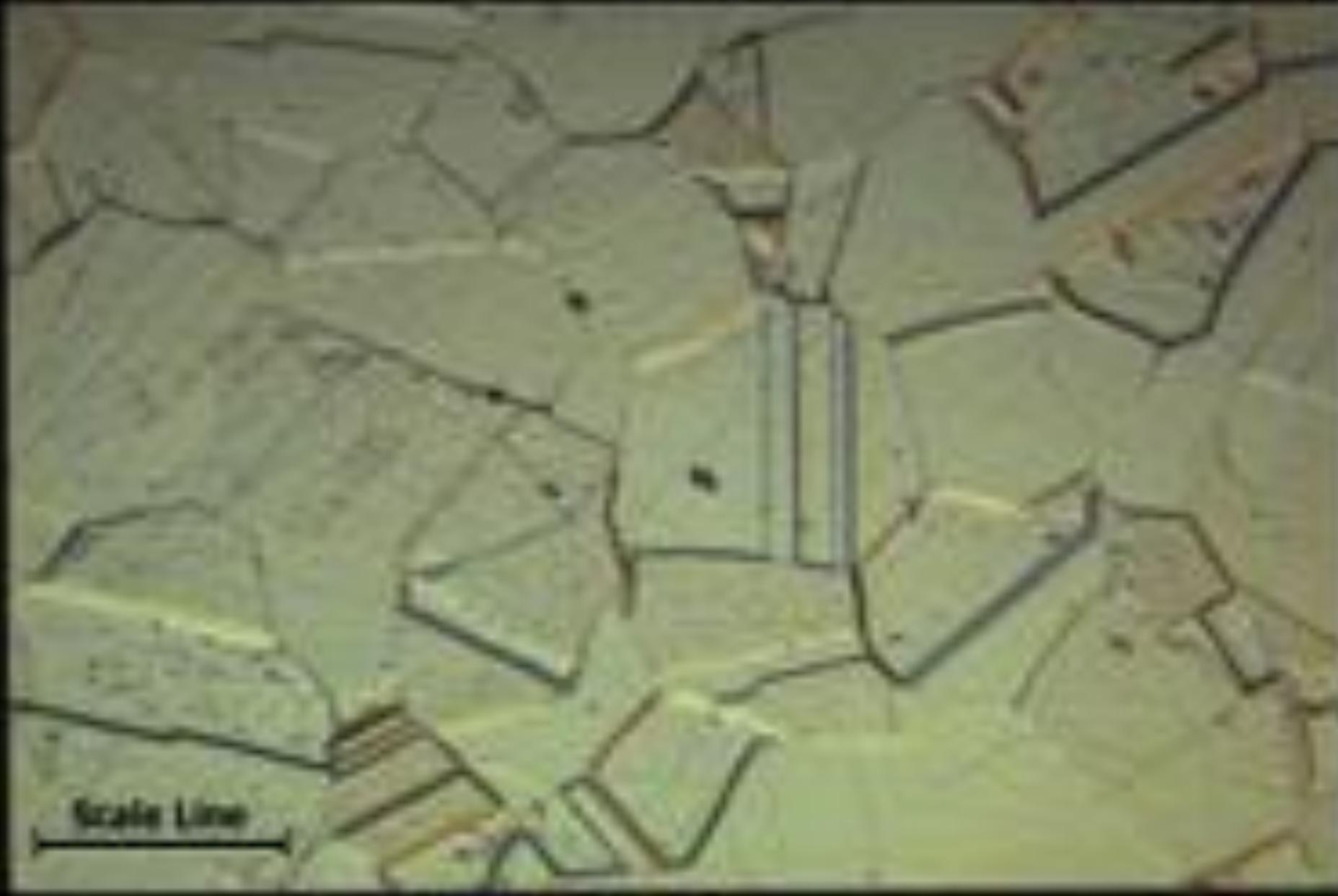
Las reglas de Hume-Rothery representan un conjunto de condiciones que deben cumplir las soluciones sólidas metálicas, para que tenga lugar la miscibilidad total entre las distintos componentes. Dichas reglas establecen que:

- 1. La diferencia entre los radios atómicos debe ser inferior al 15 por 100.*
- 2. La electronegatividad (capacidad del átomo para atraer un electrón) debe ser similar.*
- 3. Los dos metales deben poseer la misma estructura cristalina.*

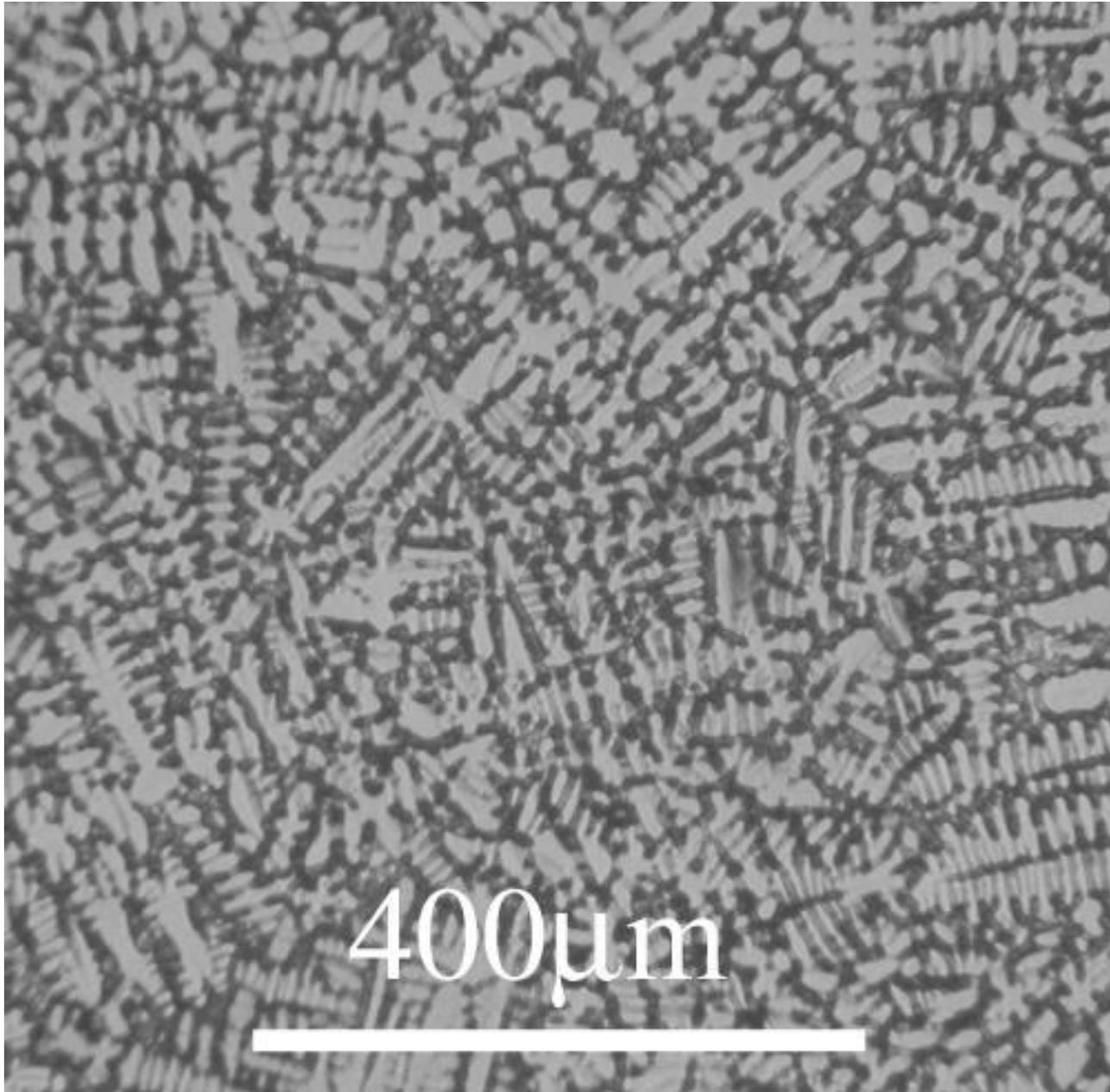
Si no se cumple una o más de las reglas de Hume-Rothery, sólo es posible obtener solubilidad parcial



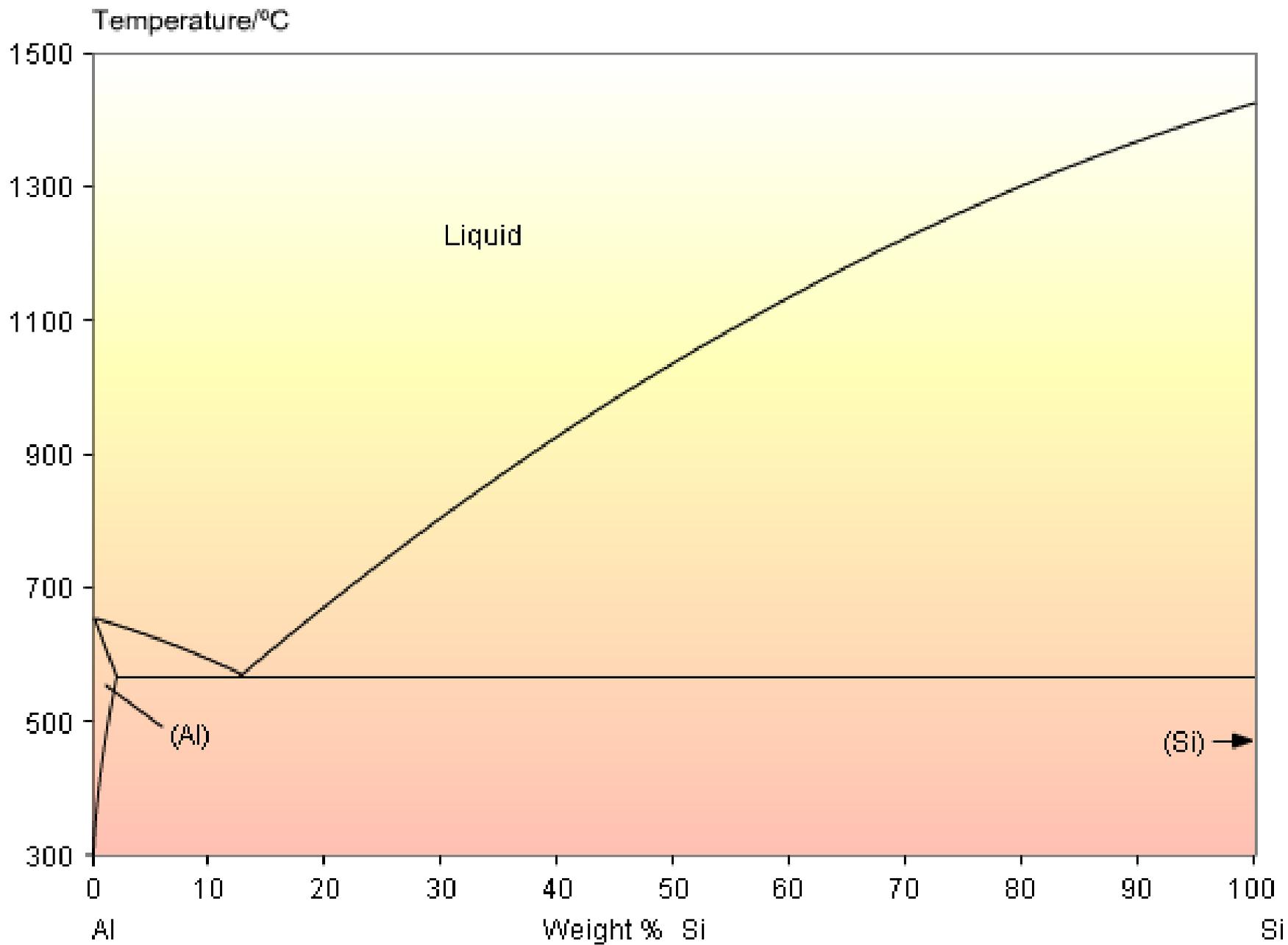




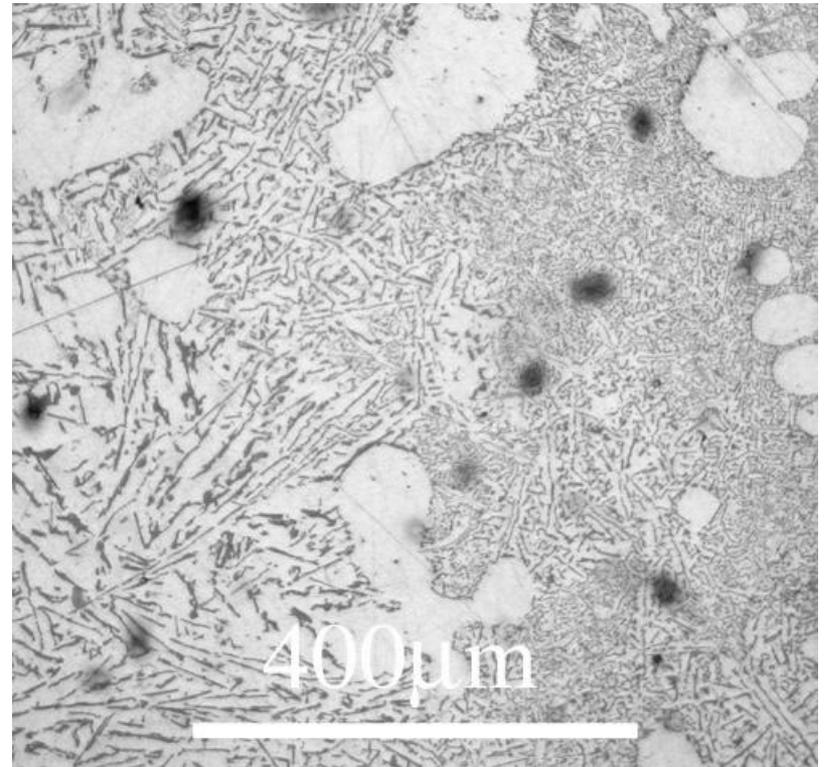
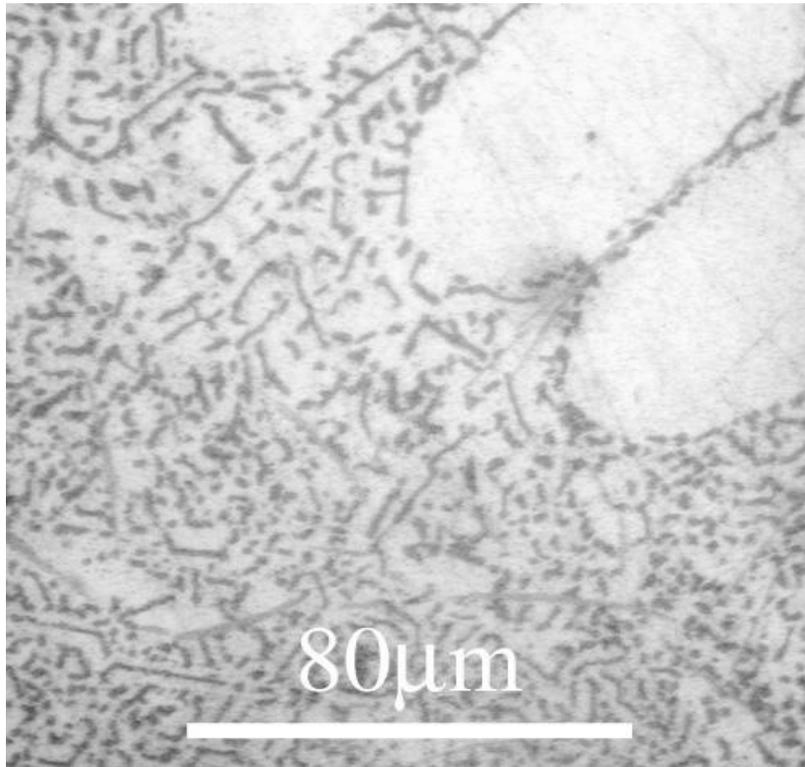
Cu 90 Ni 10



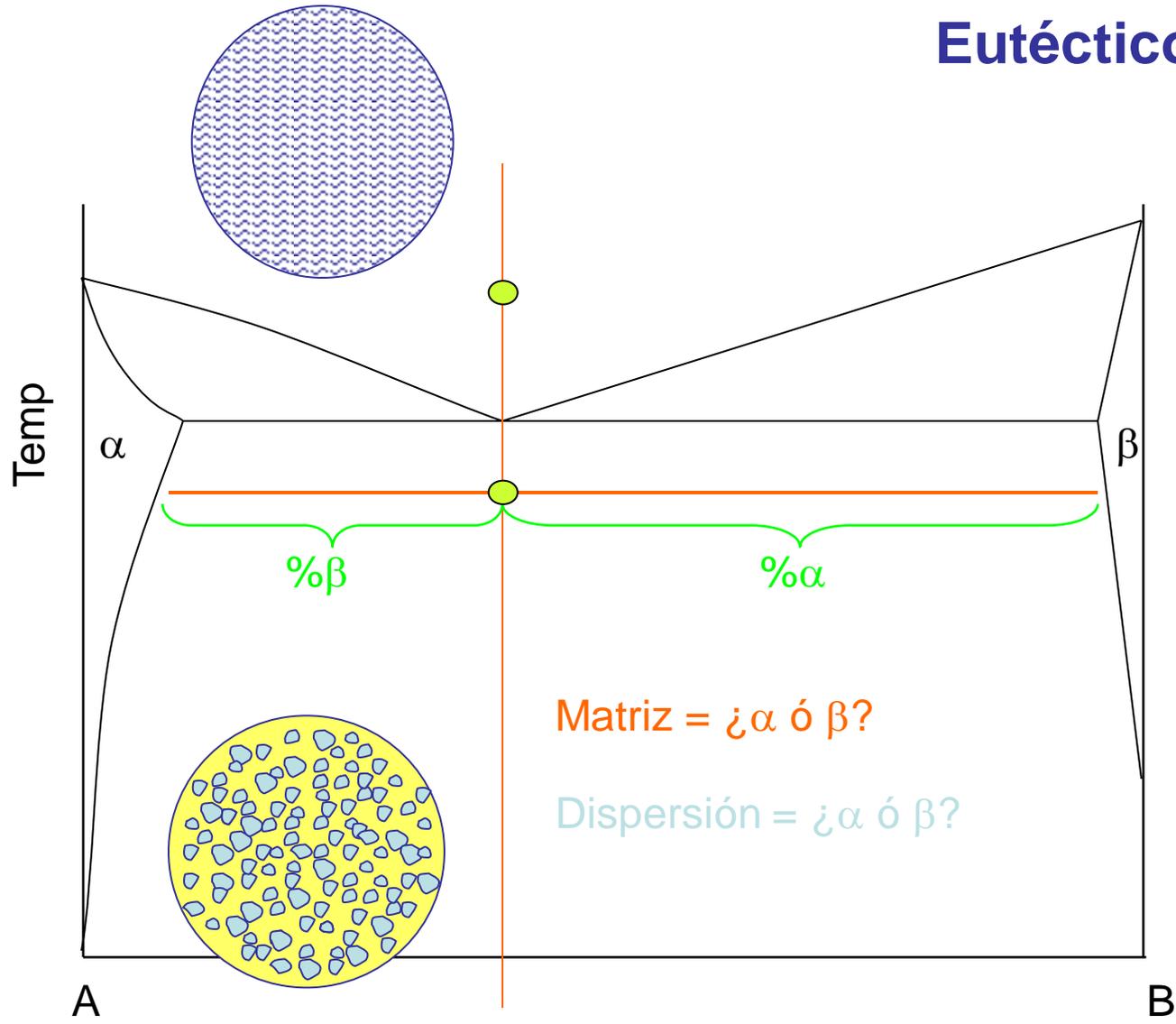
Cu 30 Ni 70



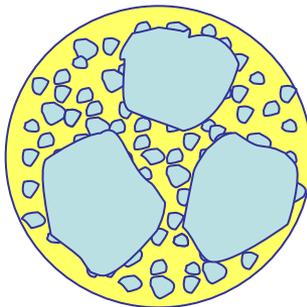
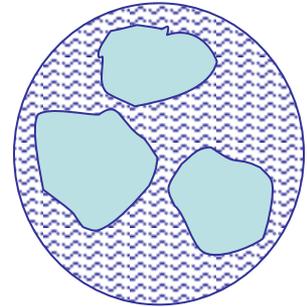
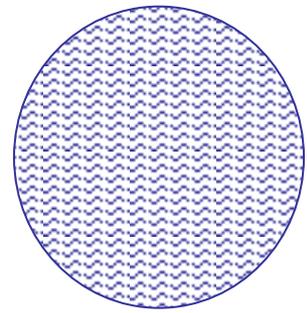
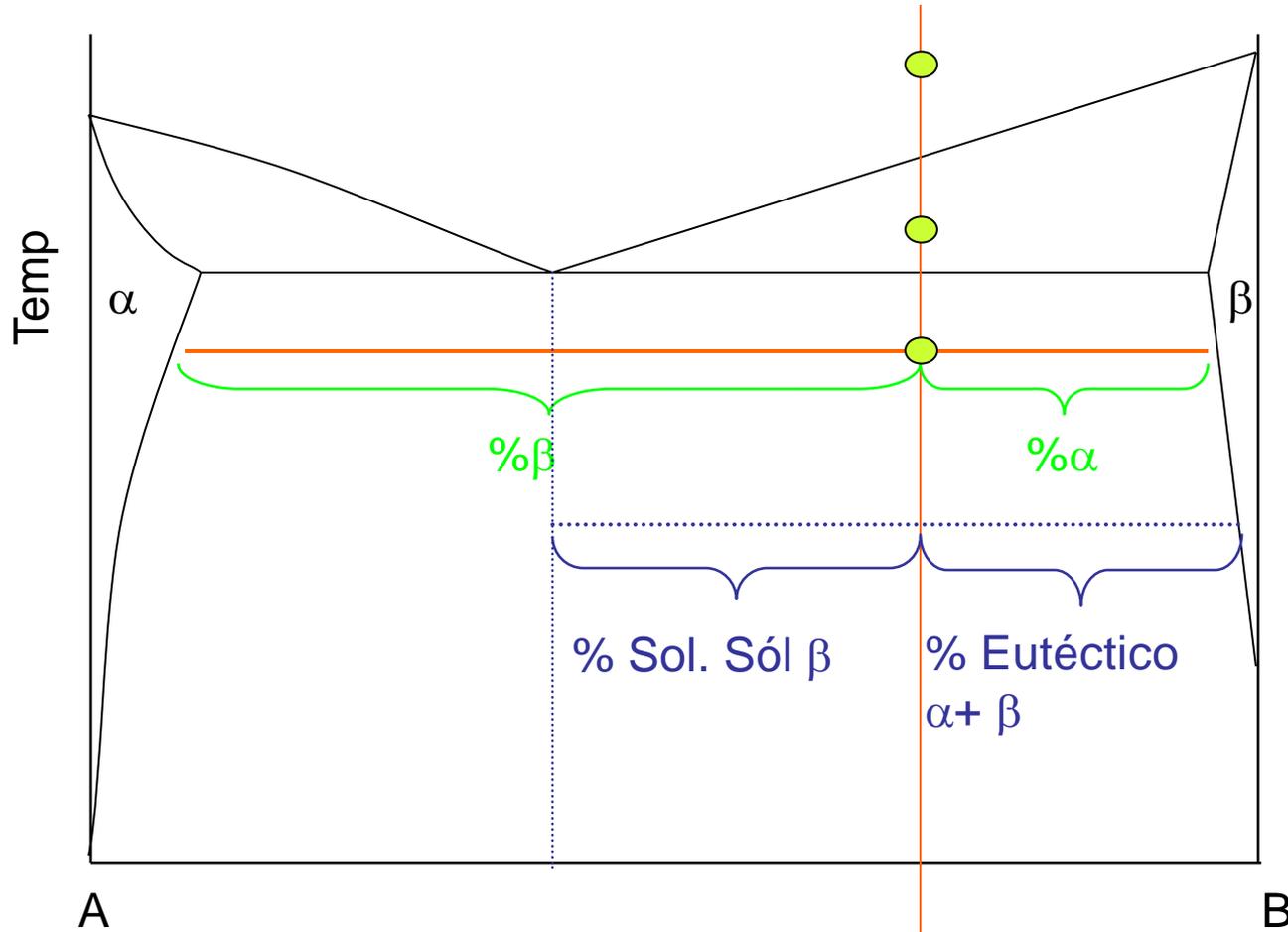
Al82% Si18%



Eutético



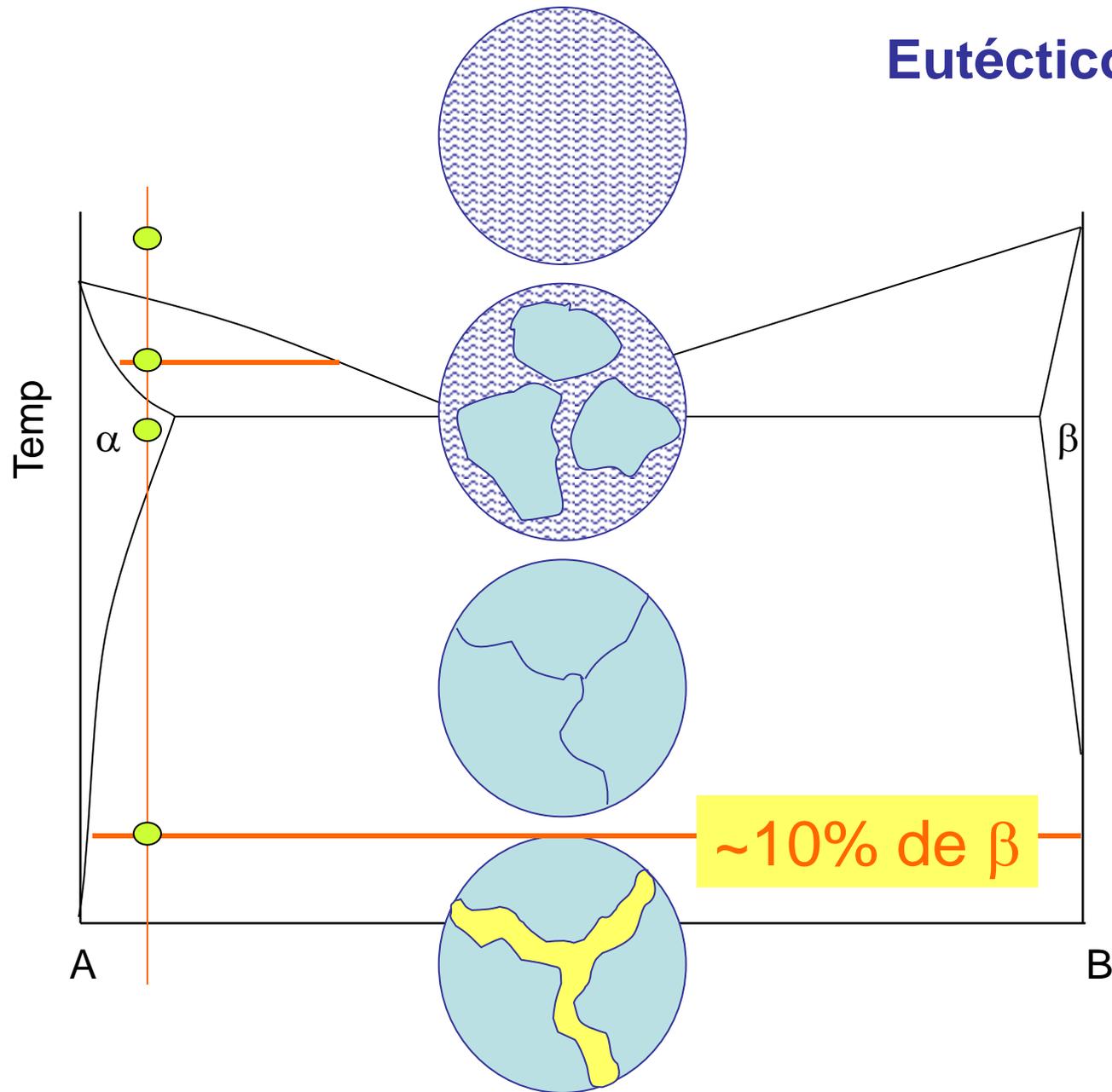
Eutético

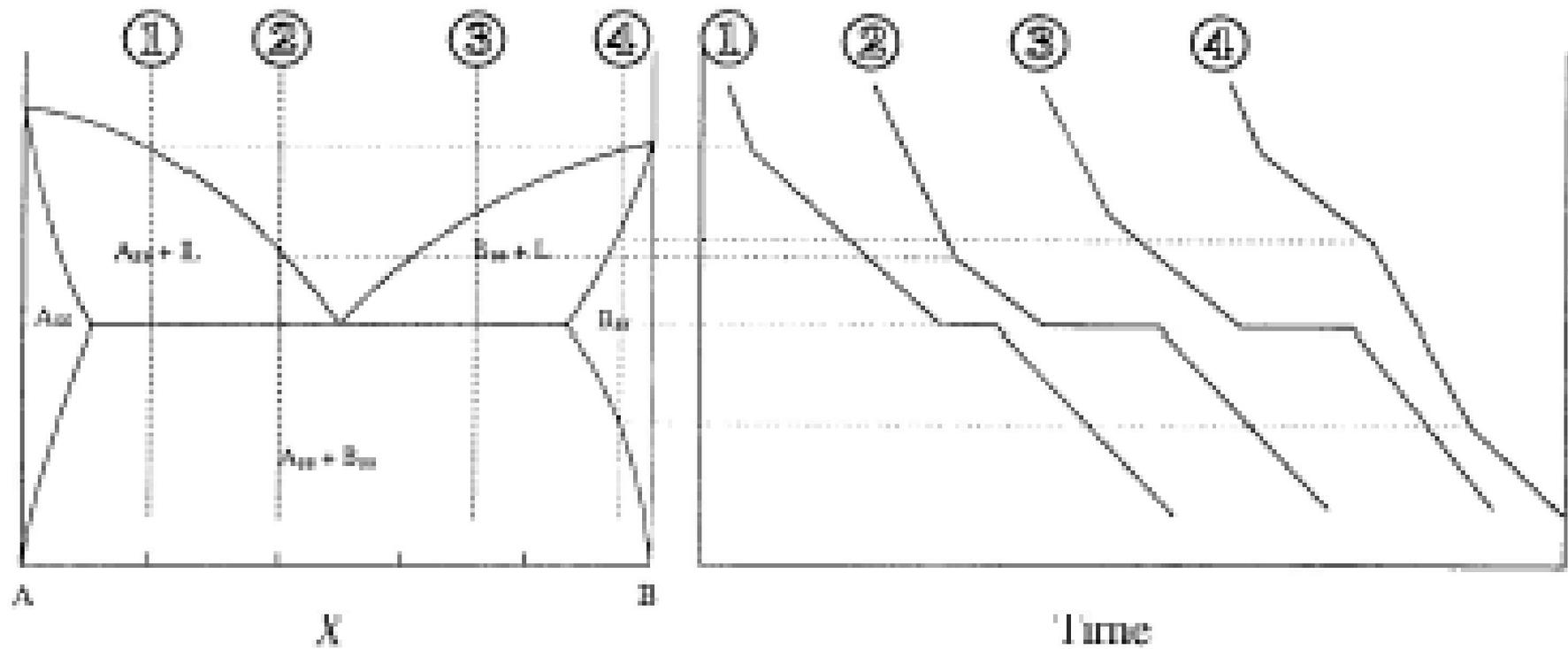


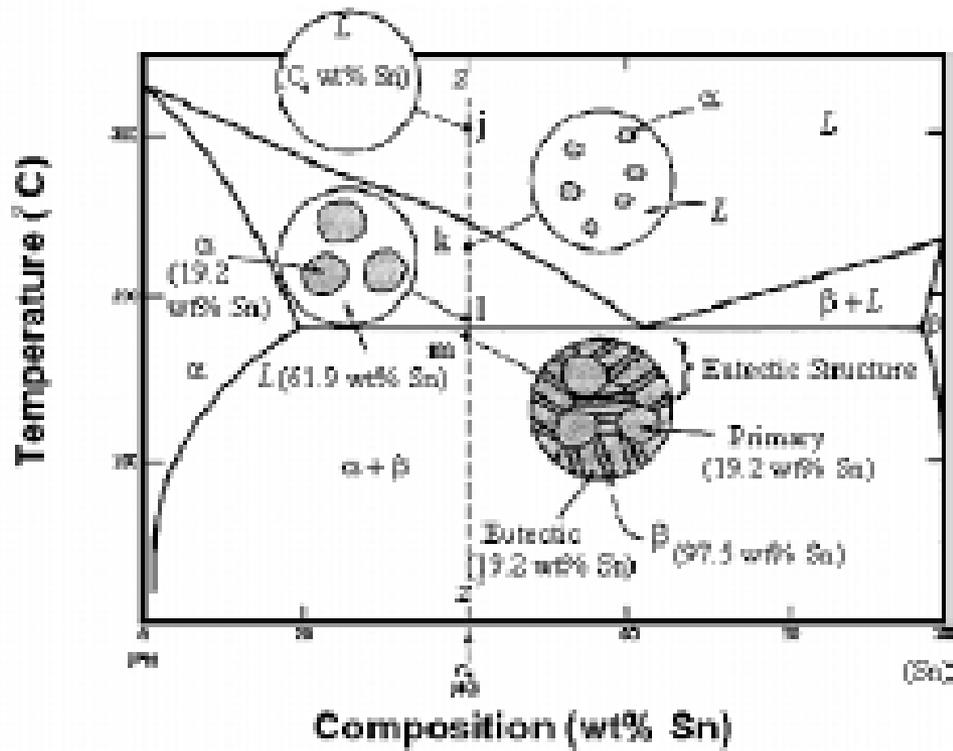
Matriz = ¿ α ó β ?

Dispersión = ¿ α ó β ?

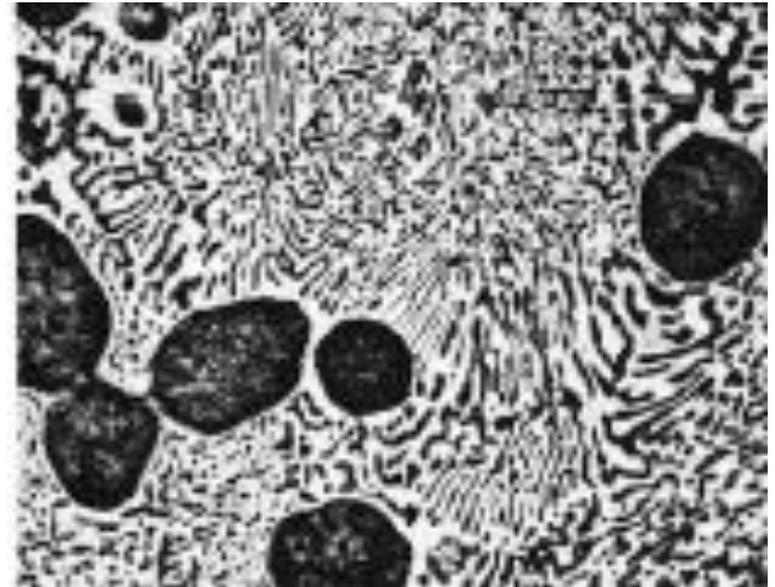
Eutético



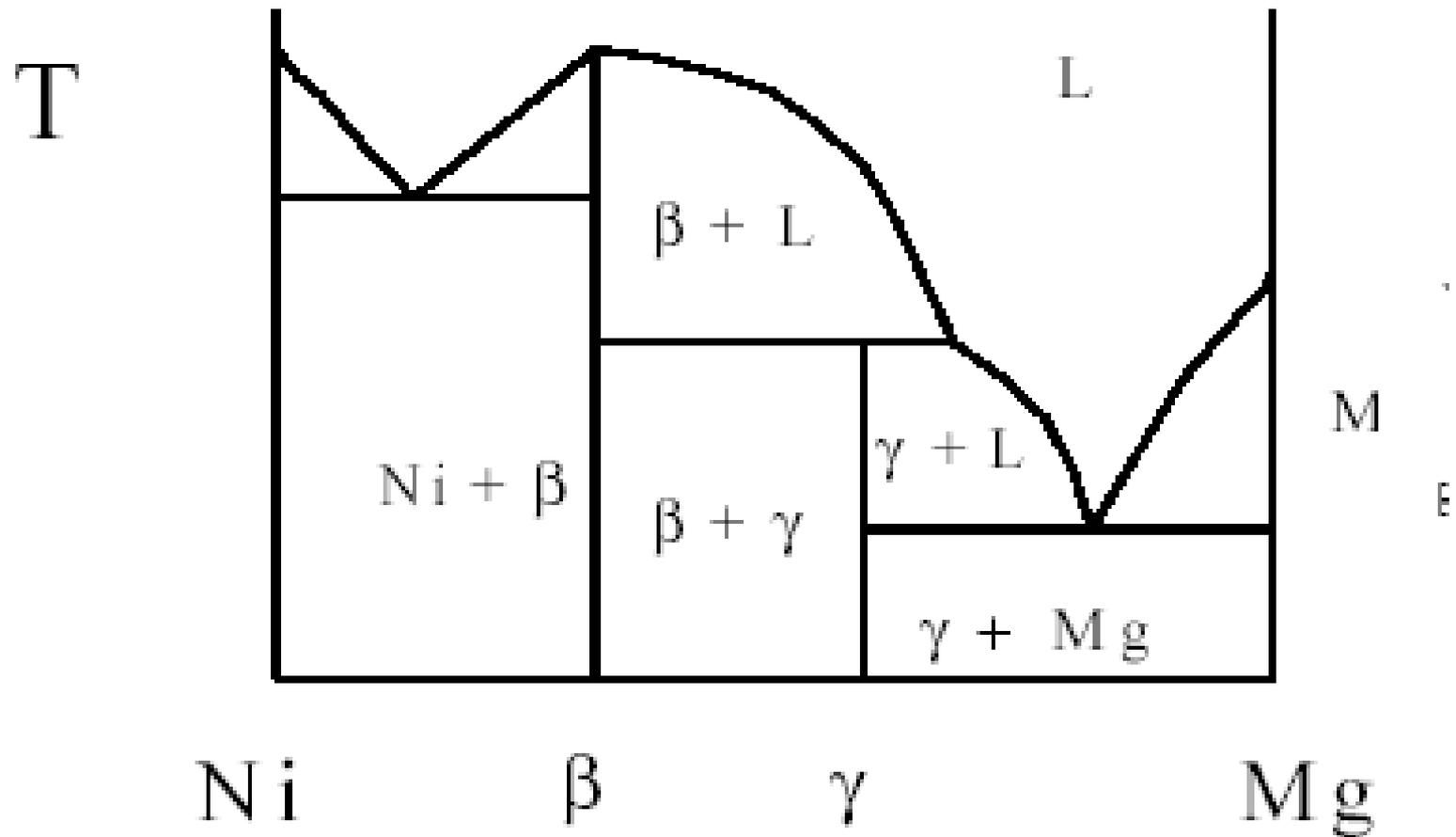




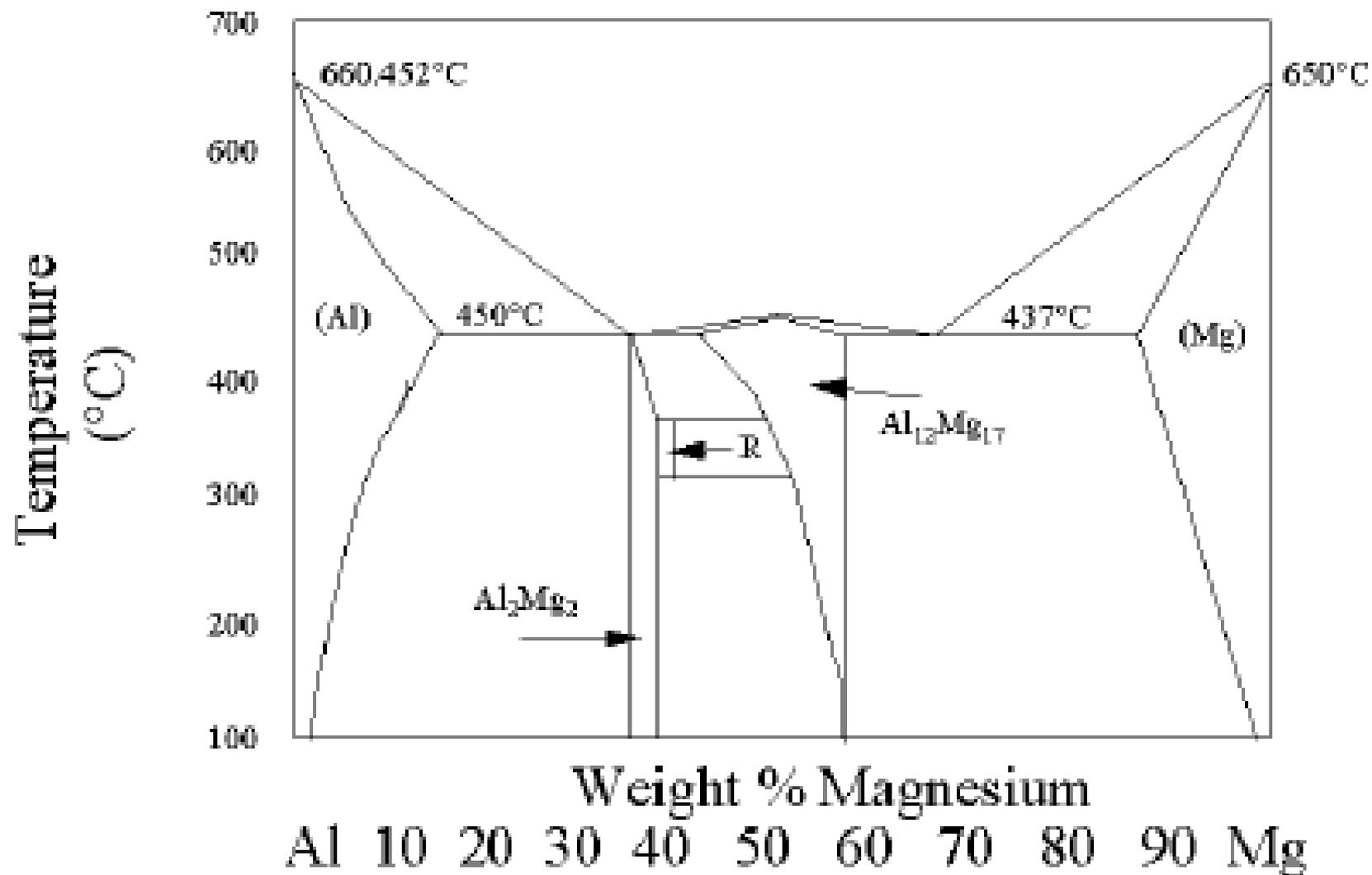
Pb Sn plomo estaño



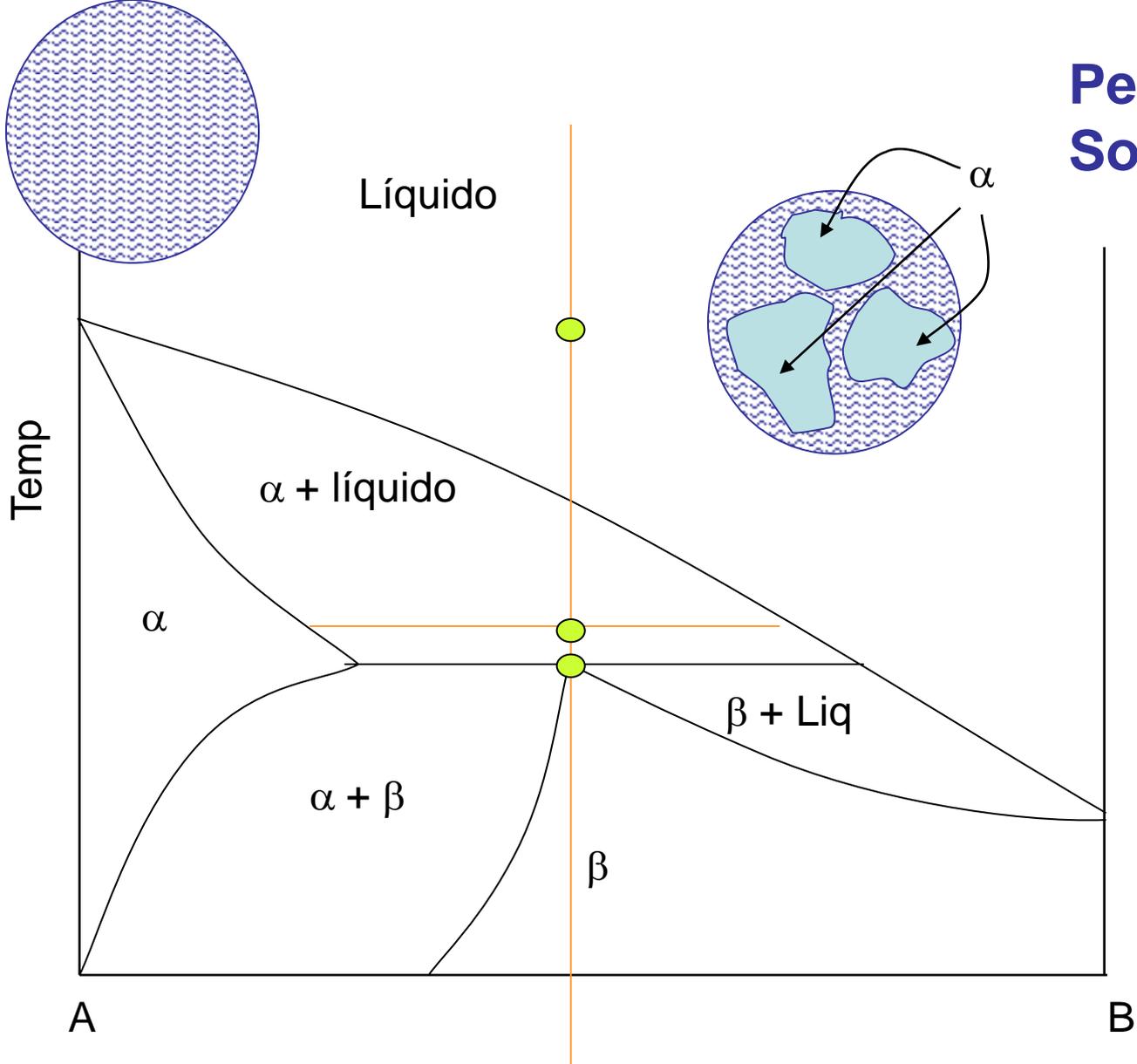
Compuesto intermetálico

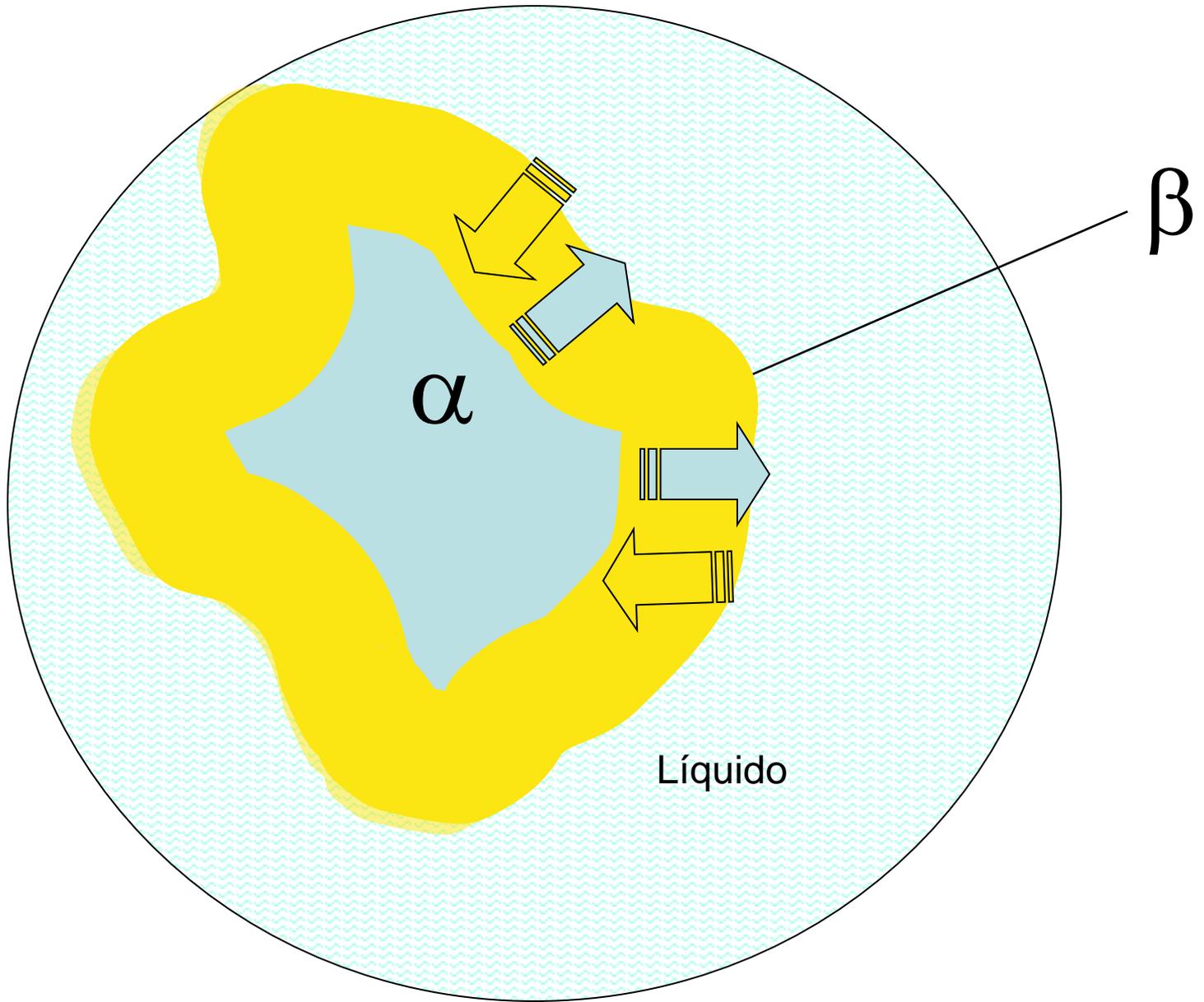


Al-Mg

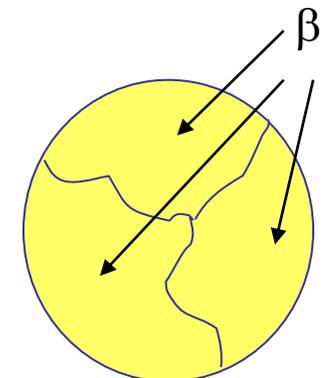
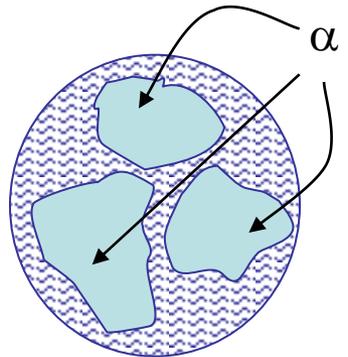
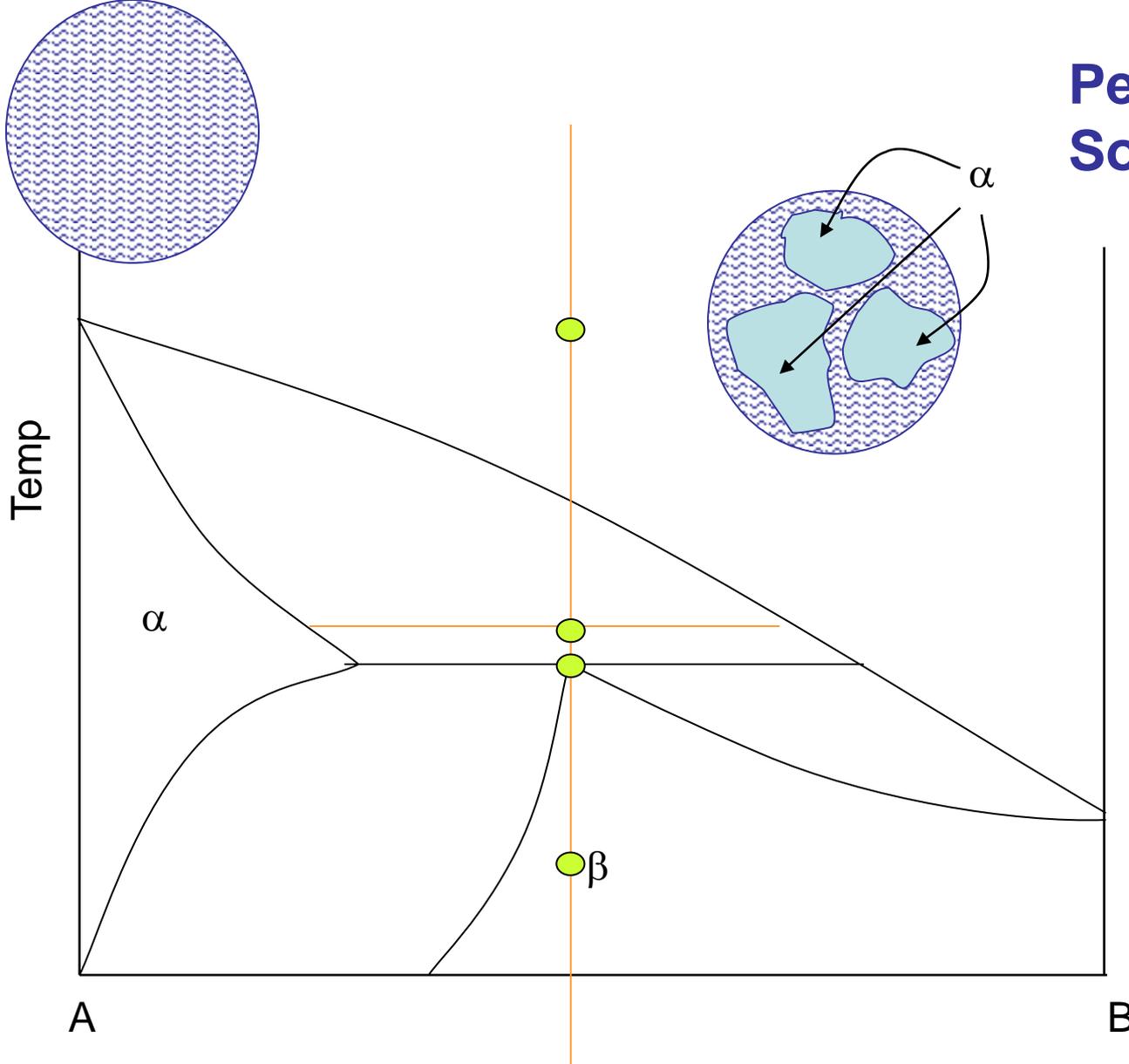


Peritético puro Solución Sólida

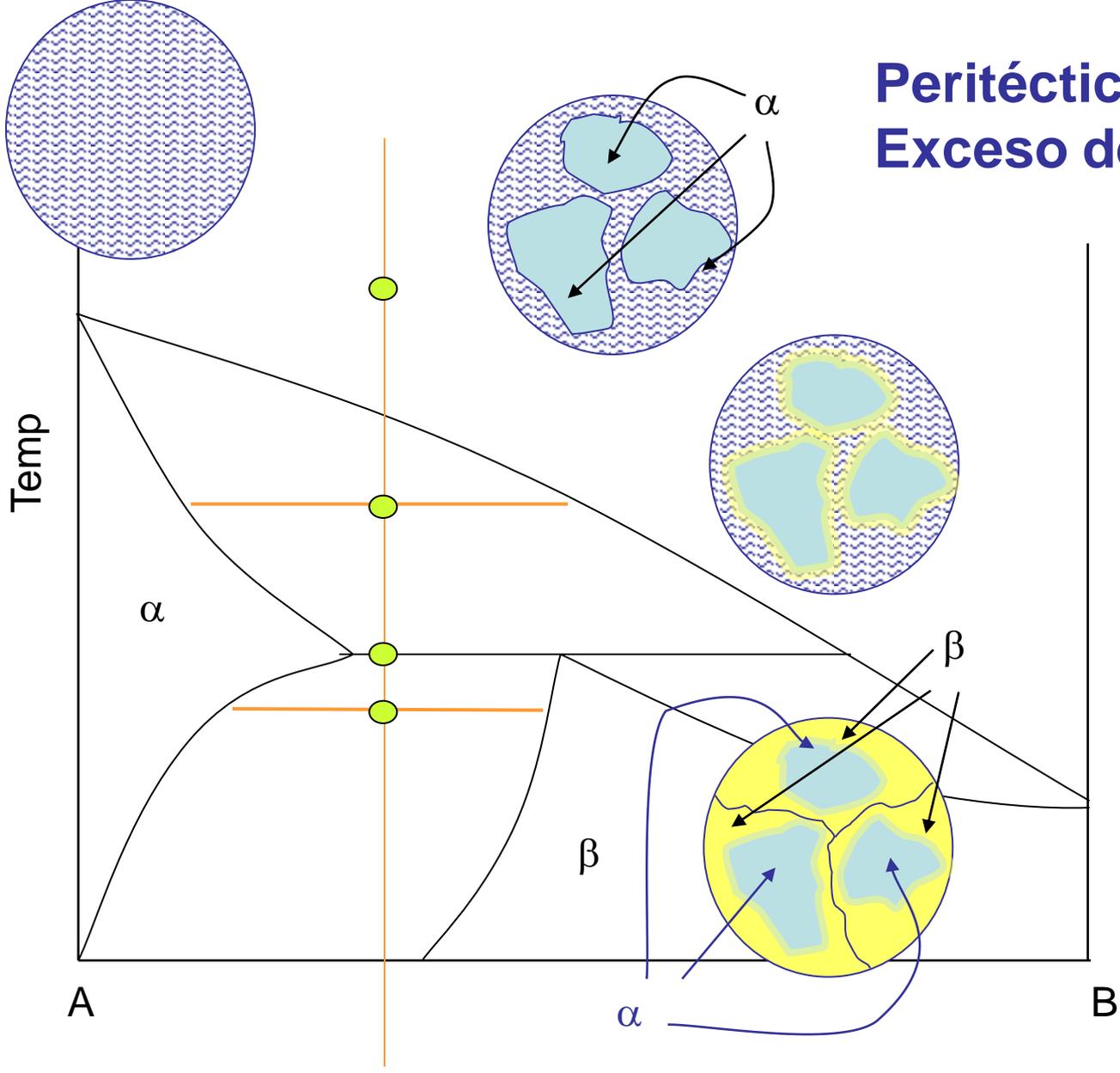




Peritético puro Solución Sólida

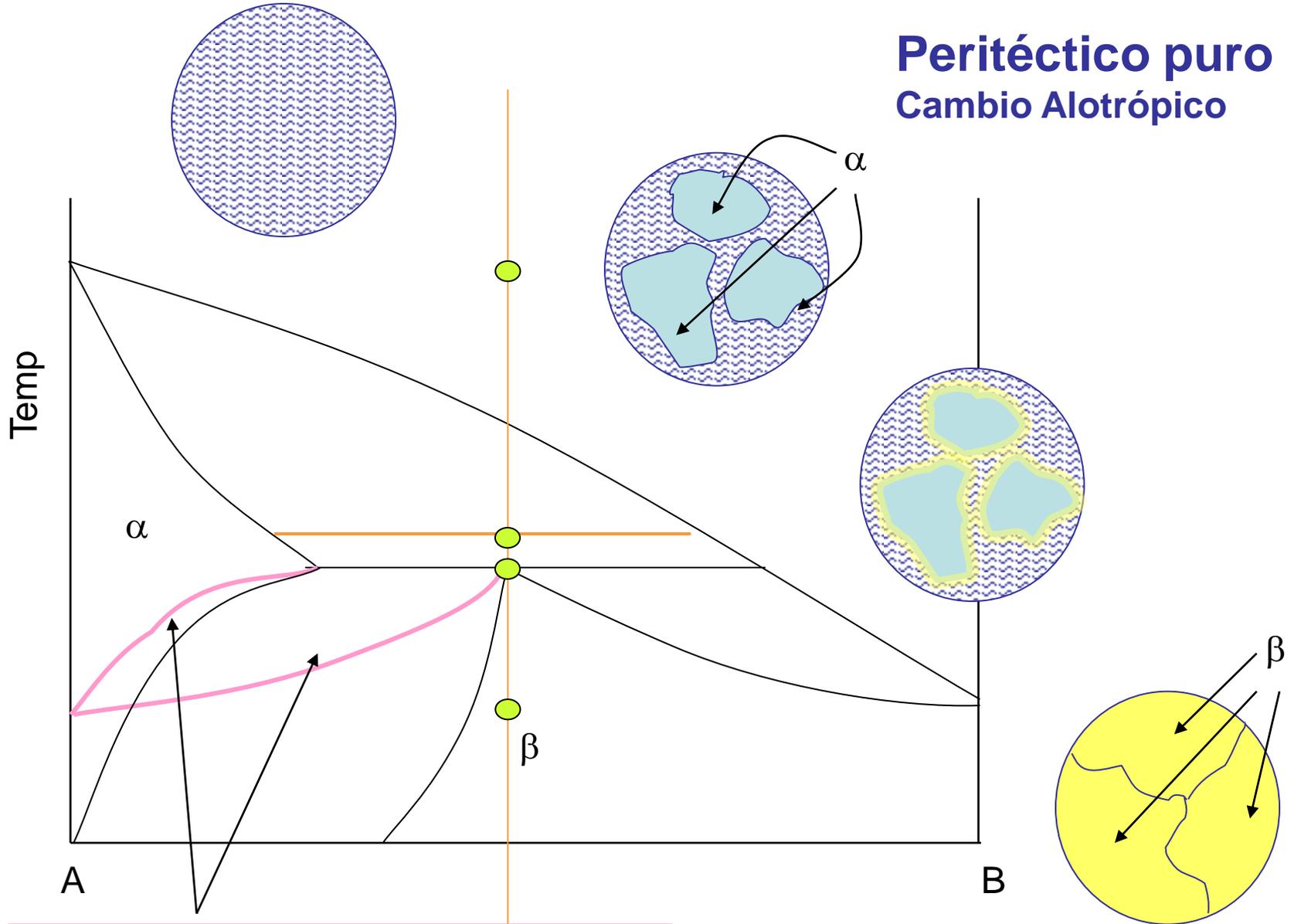


Peritético incompleto Exceso de Sólido



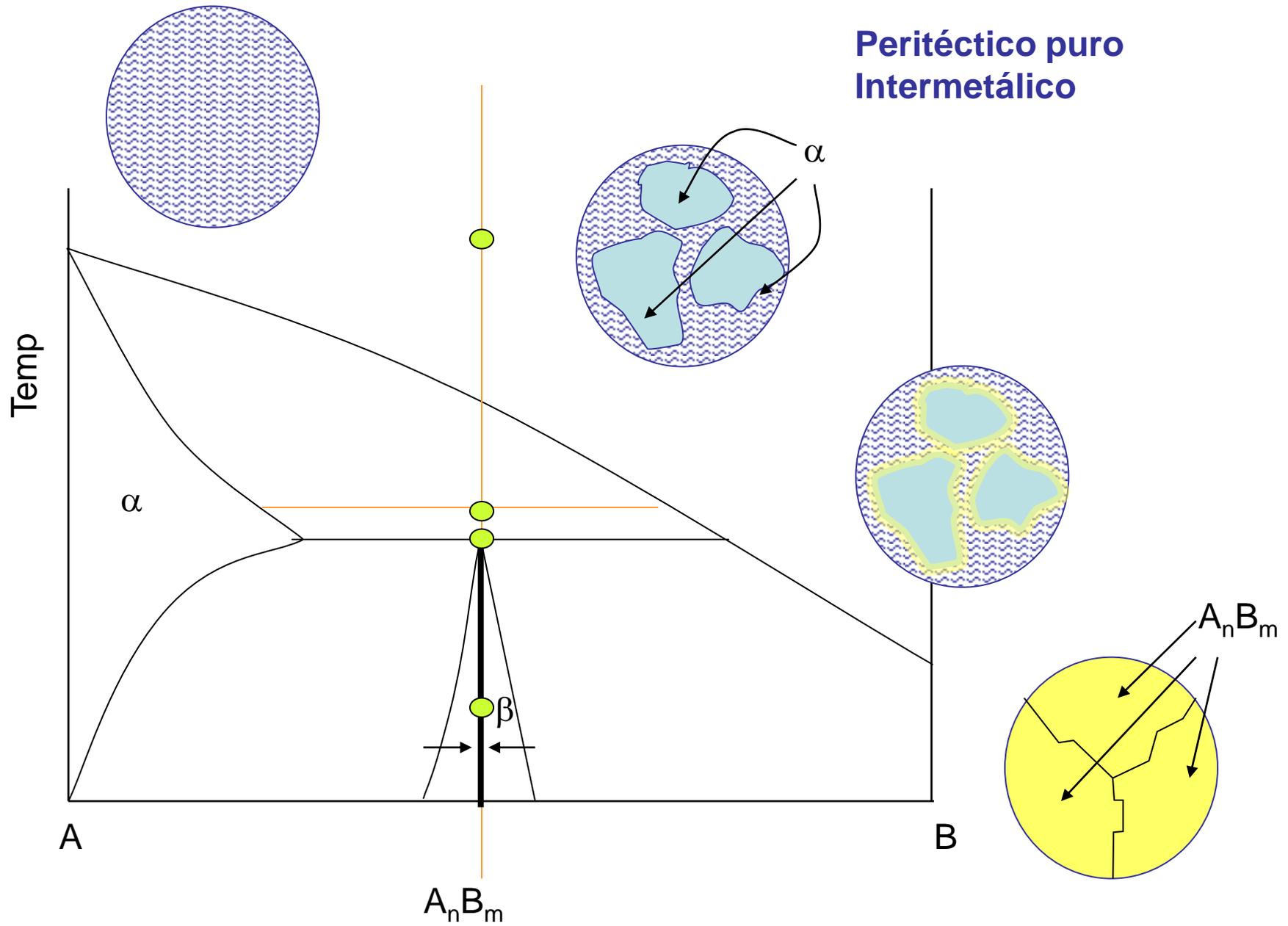
Peritético puro

Cambio Alotrópico

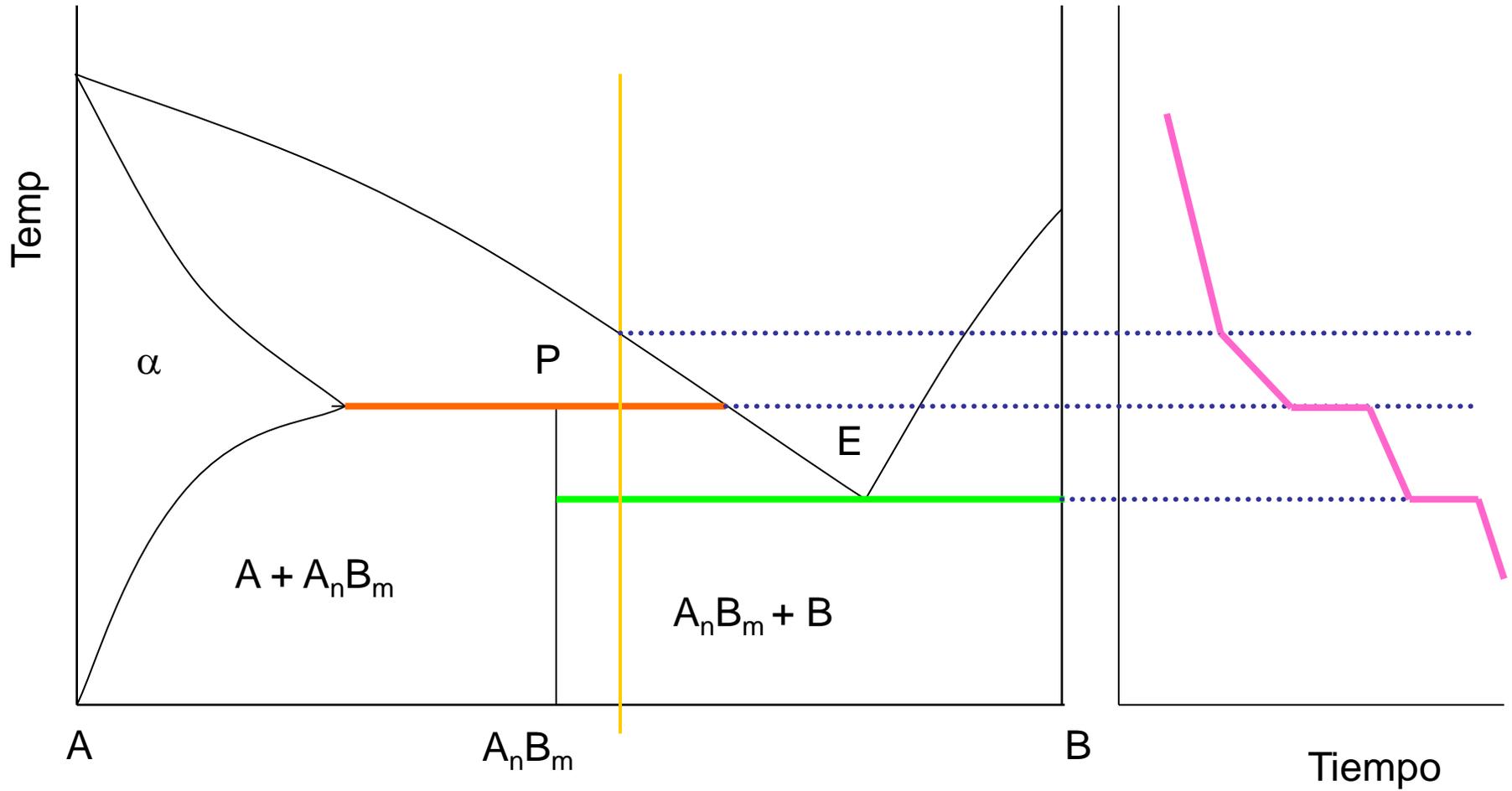


Curvas de cambio alotrópico

Peritético puro Intermetálico

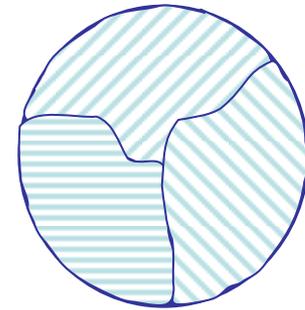
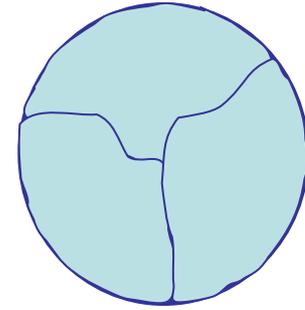
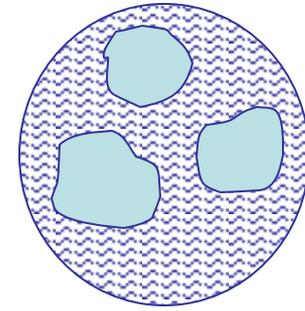
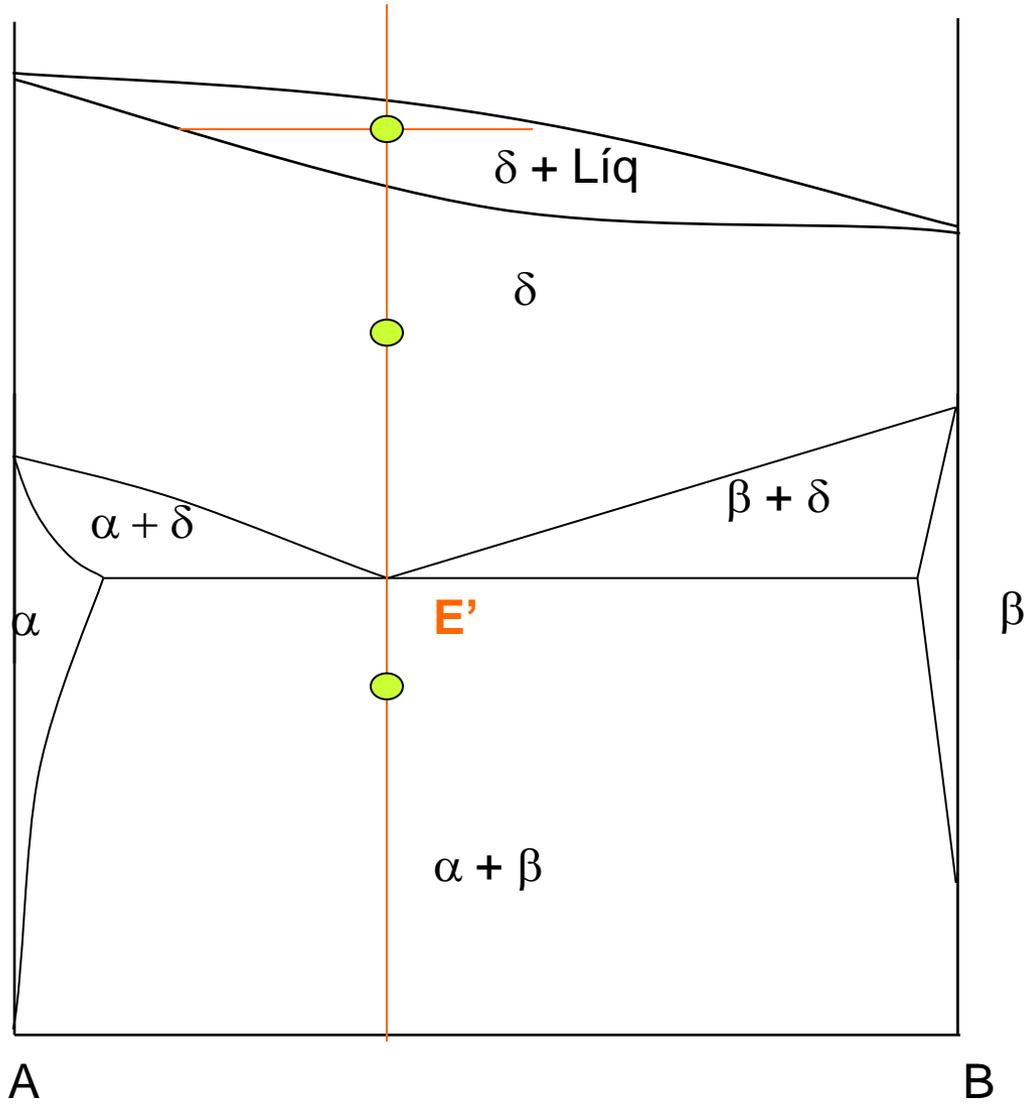


Peritético + Eutético



líquido

Temp



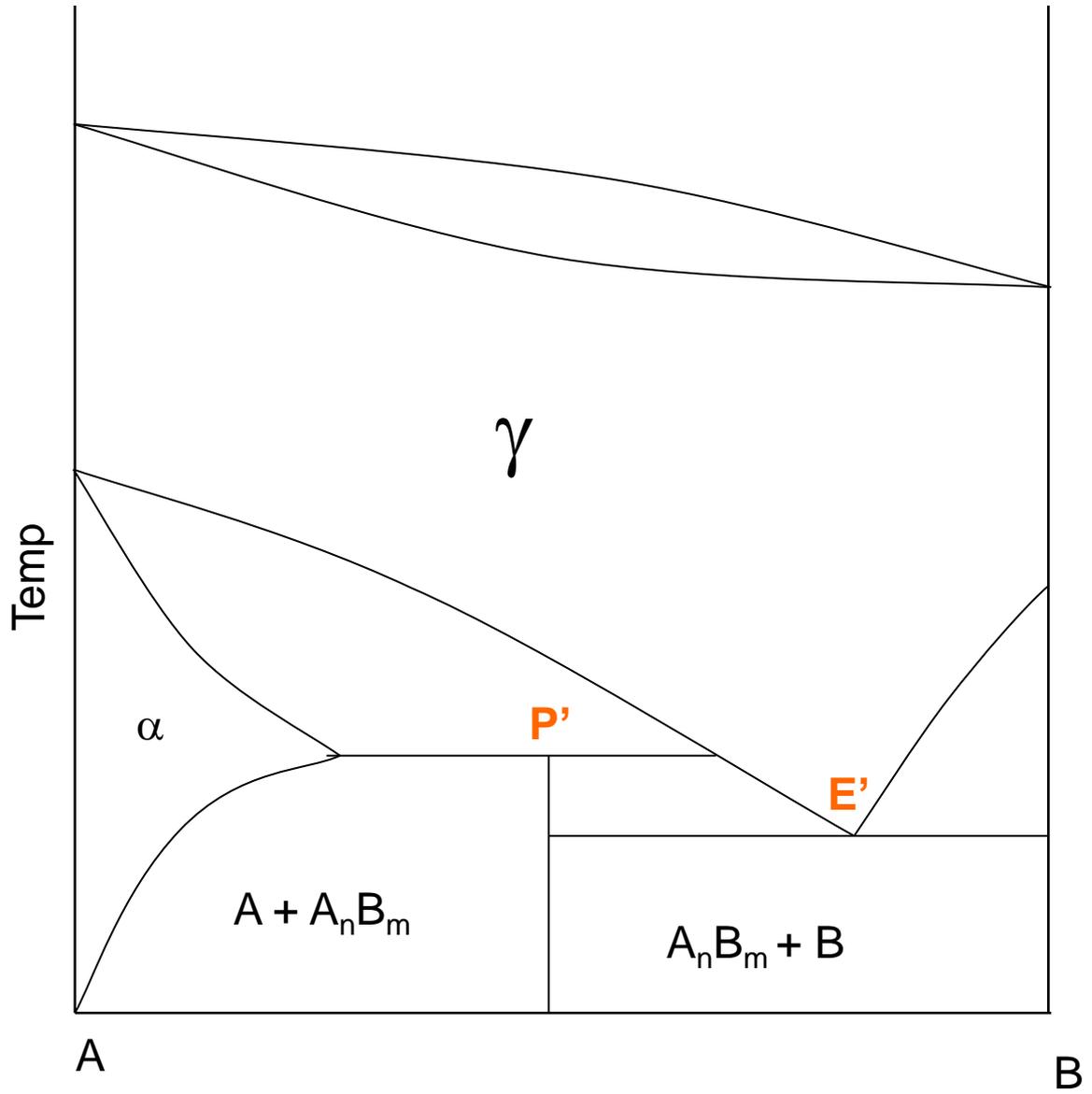
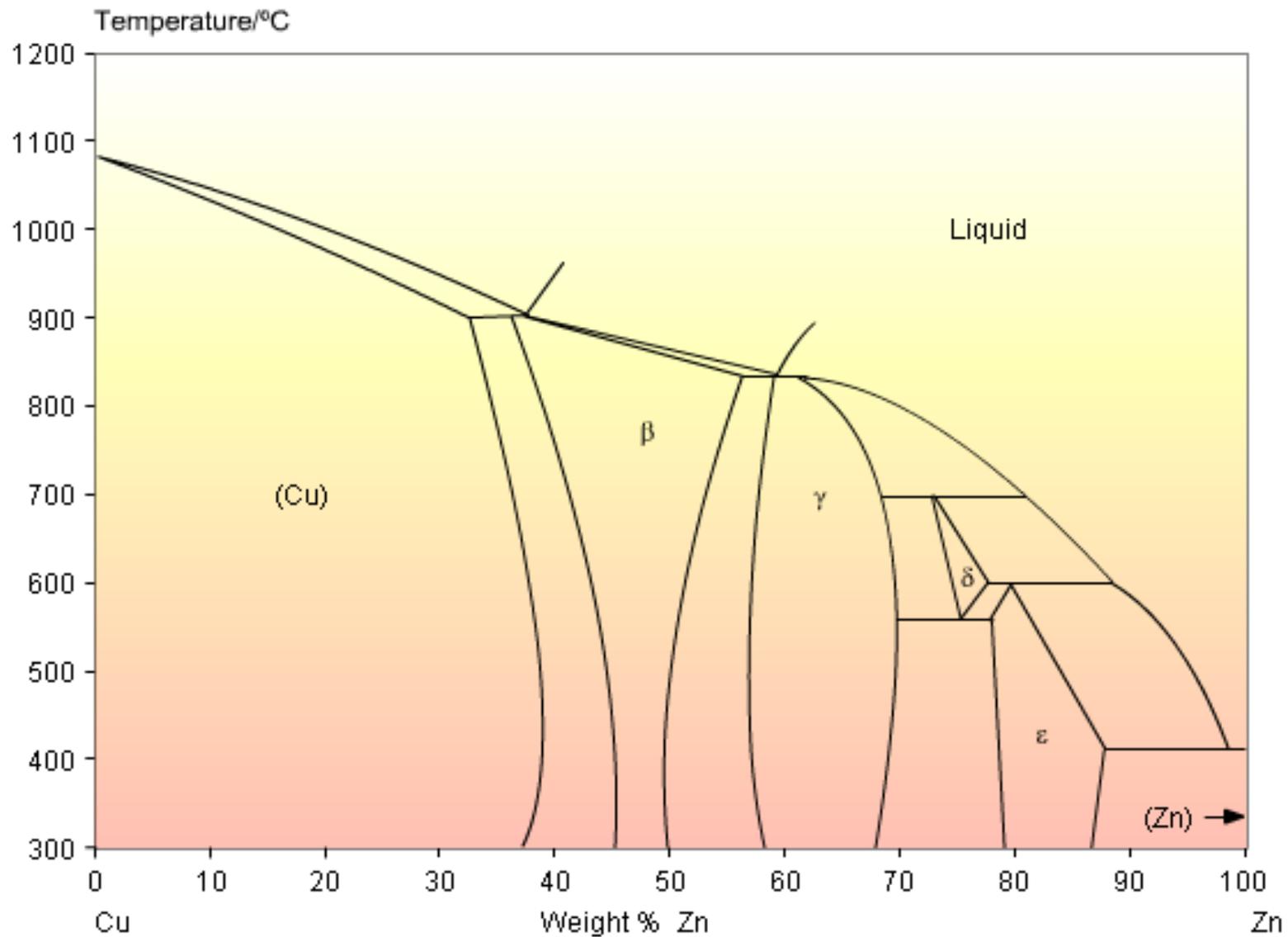
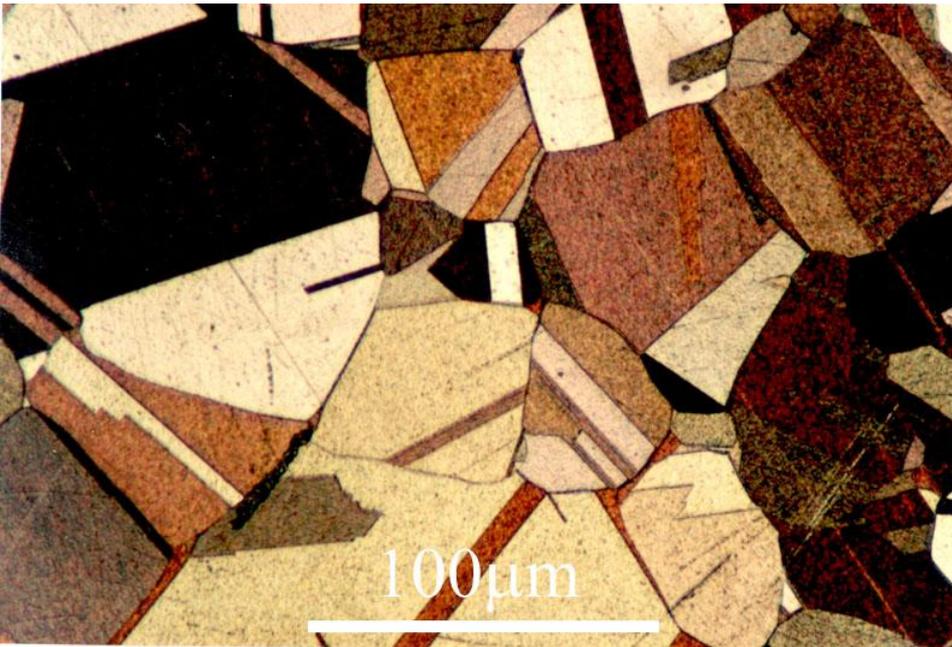


Diagrama Cu-Zn

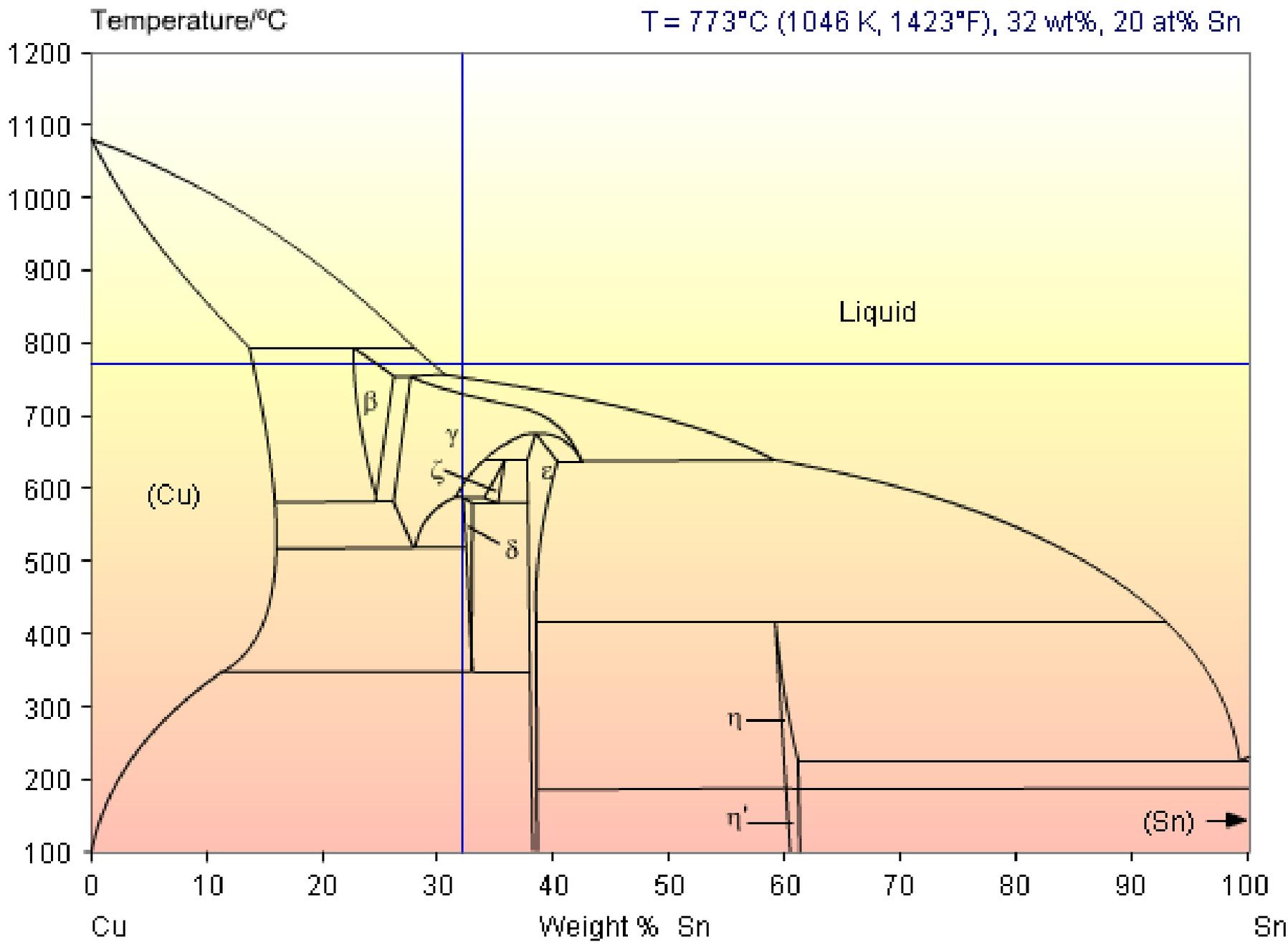


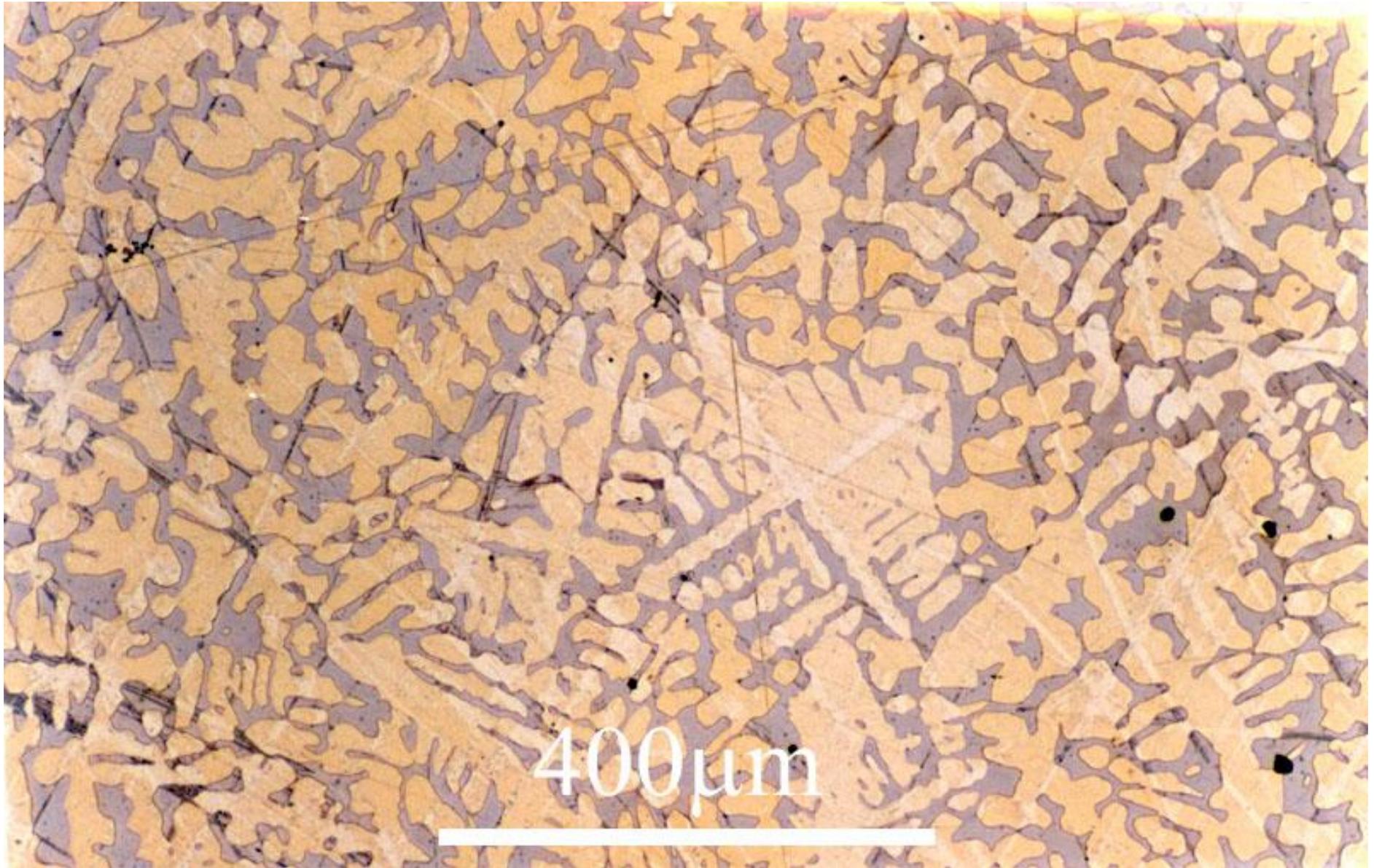
Cu70%
Zn30%



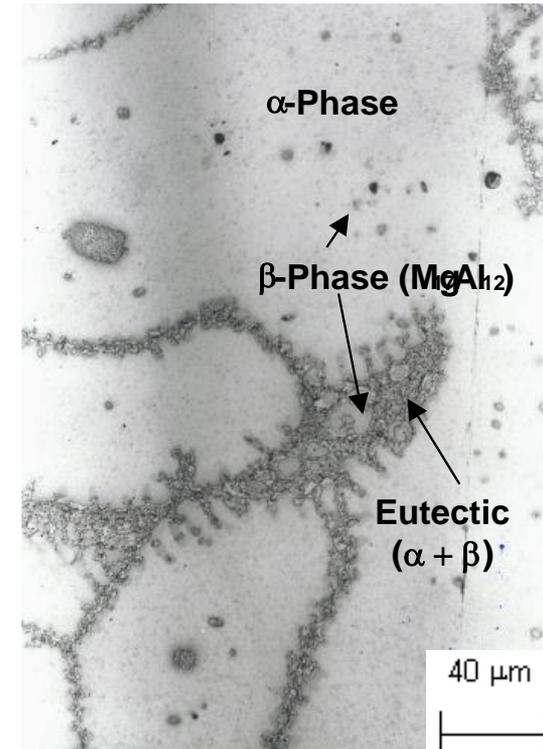
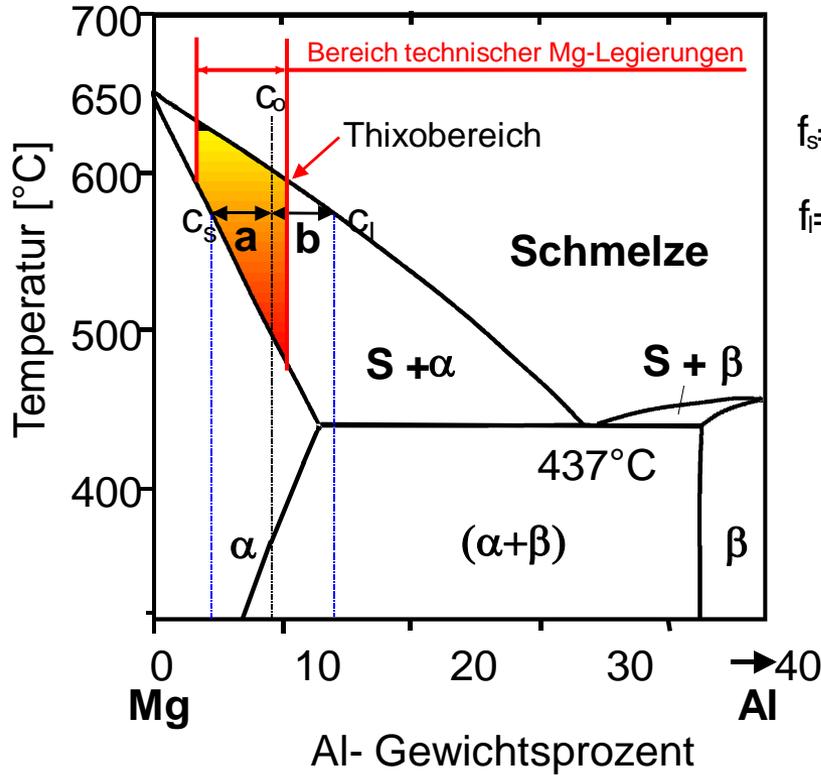
Cu55%
Zn45 %





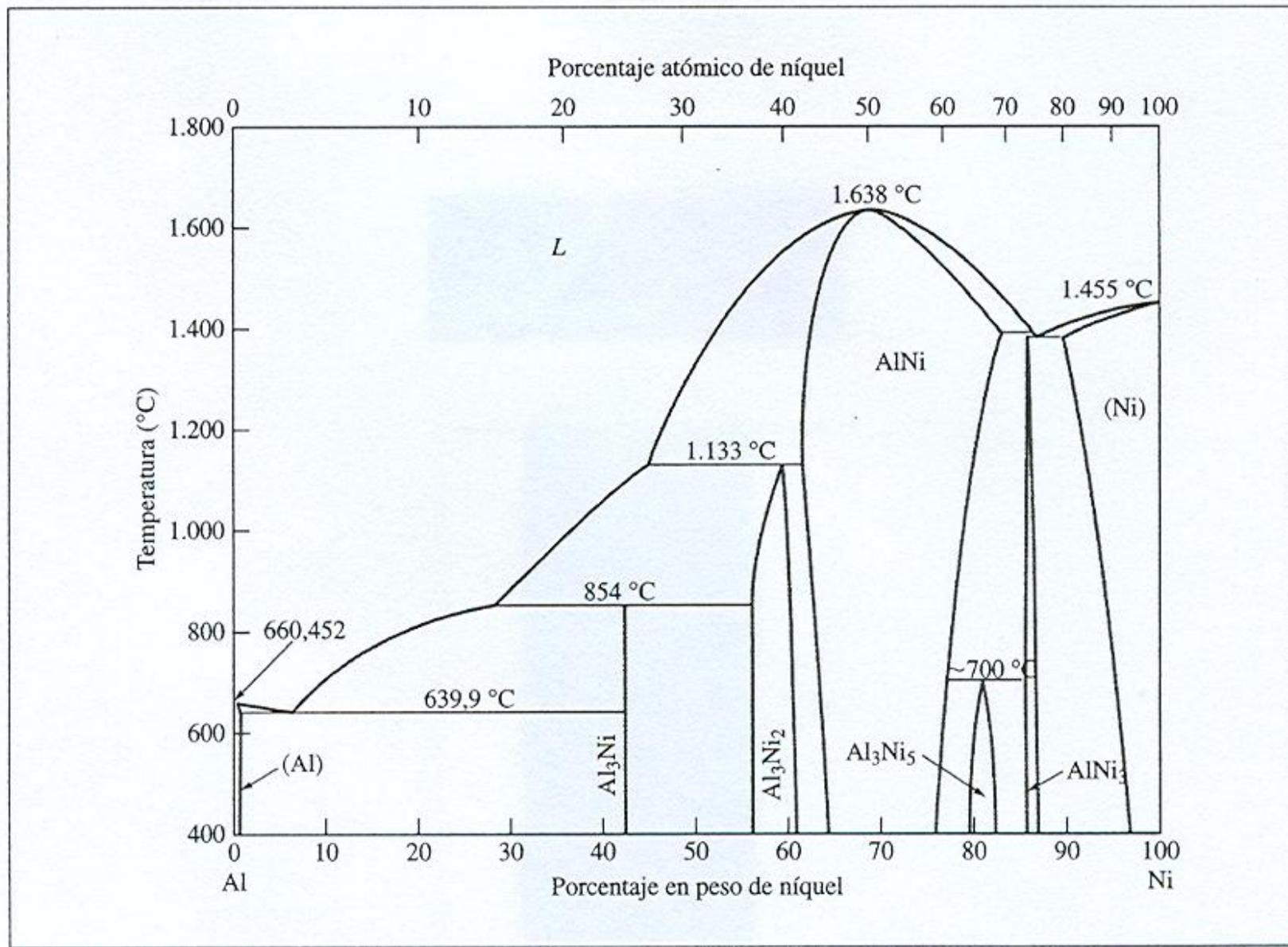


Cu 80 Sn 20



MgAl9Zn
Thixo-Vormaterial

Zustandsdiagramm des Systems Mg-Al



(Según Binary Phase Diagrams, ASM Int., 1986, p. 142.)

FIGURA 8.33. Diagrama de fases aluminio-níquel.

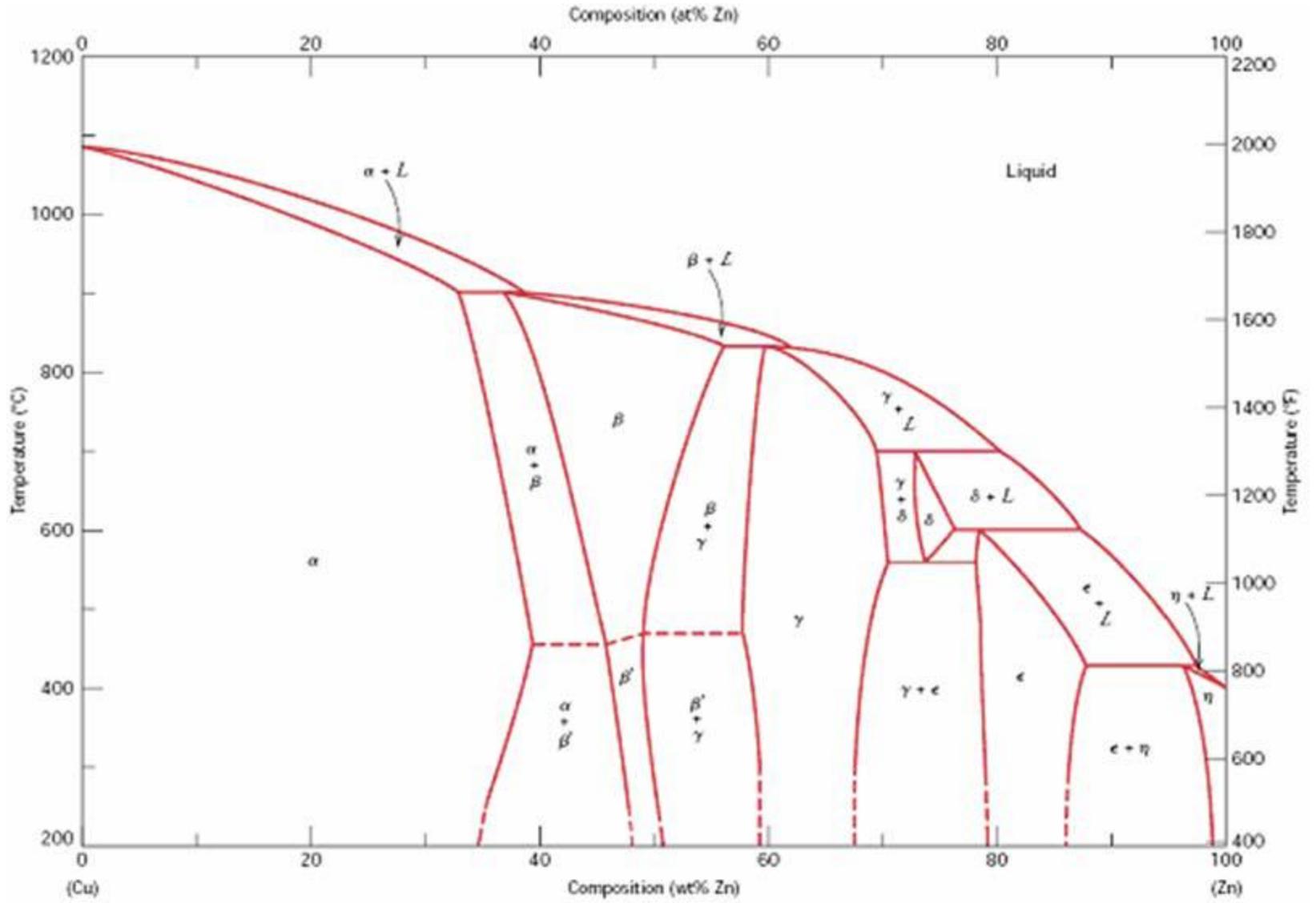
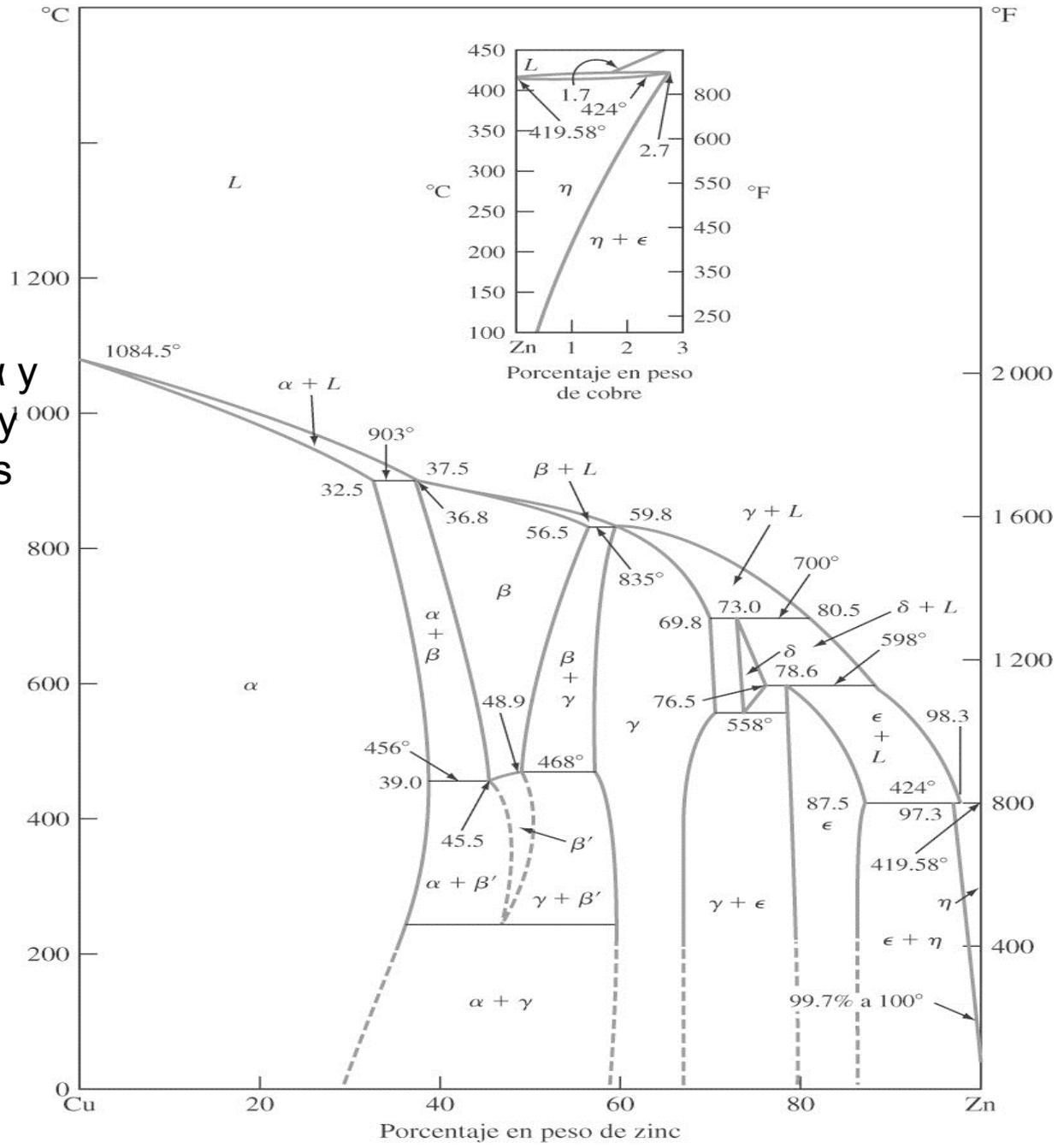


Diagrama de fases Cu-Zn

Diagrama de fases cobre-zinc.
 Este diagrama tiene las fases α y η terminales y las fases β , γ , δ y ϵ intermedias. Hay cinco puntos peritéticos invariantes y un punto eutectoide.



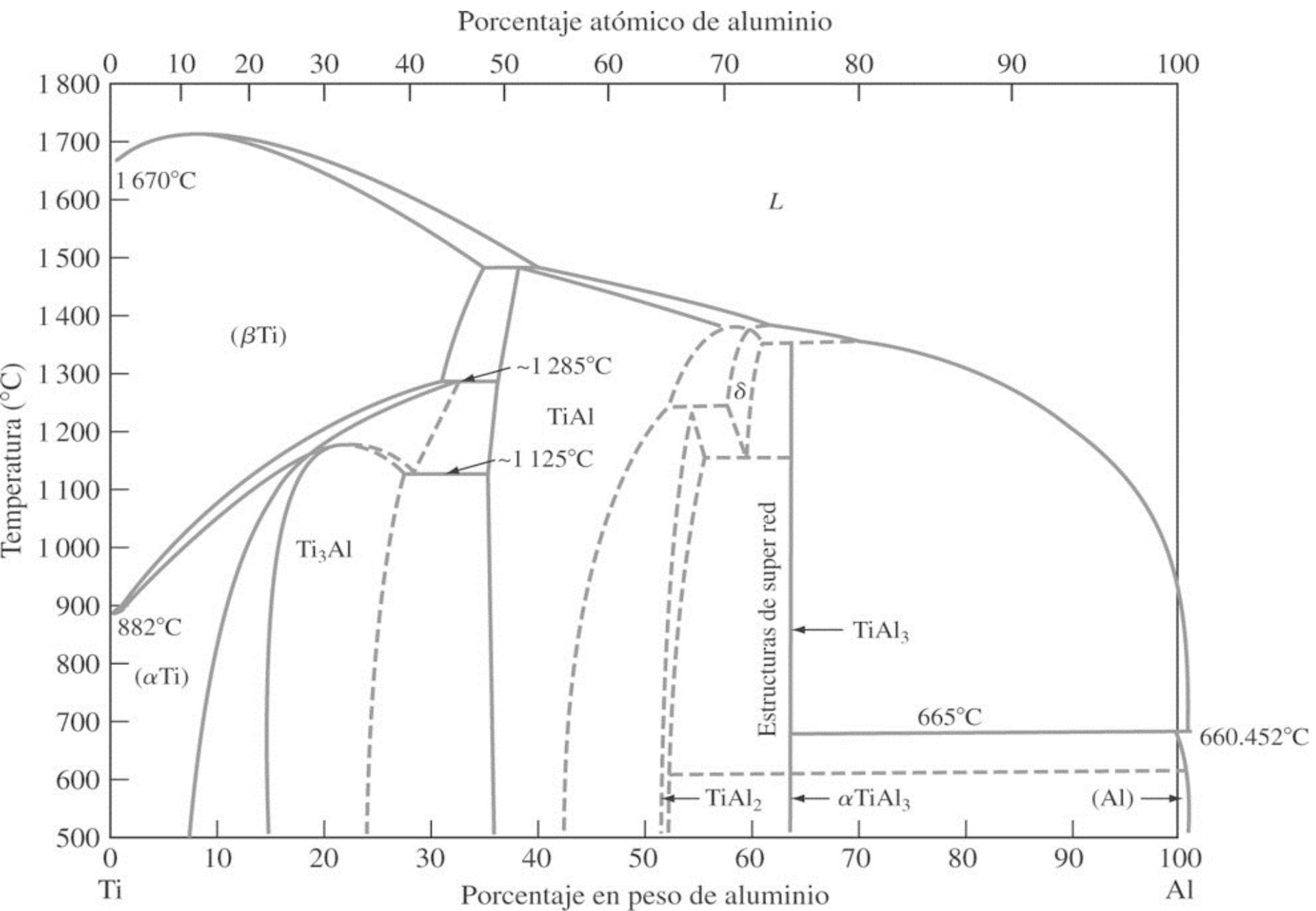
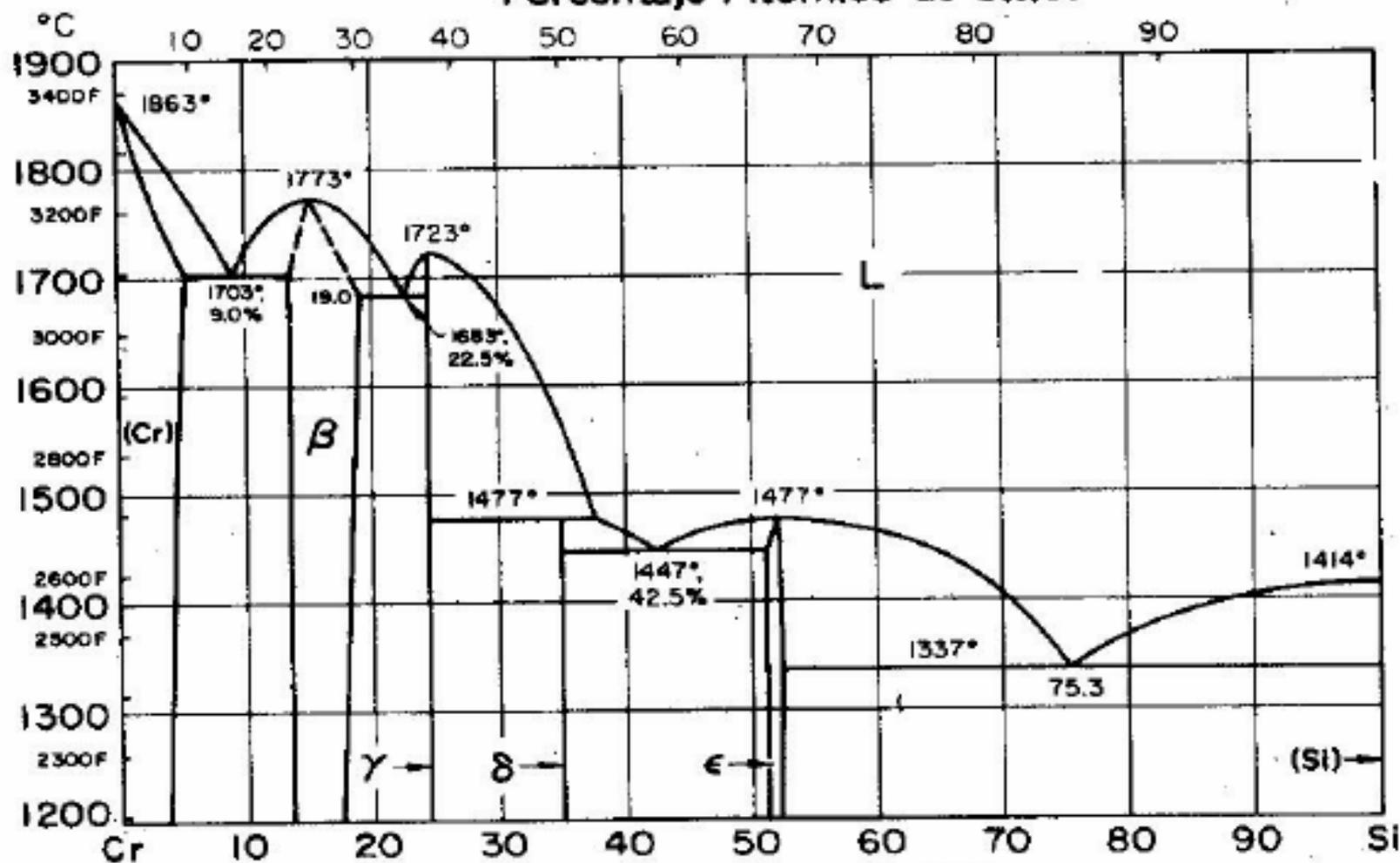


Diagrama de fases titanio-aluminio.

Cr-Si Cromo-Sílice

Porcentaje Atómico de Sílice



Donald T. Hawkins

Porcentaje en Peso de Sílice

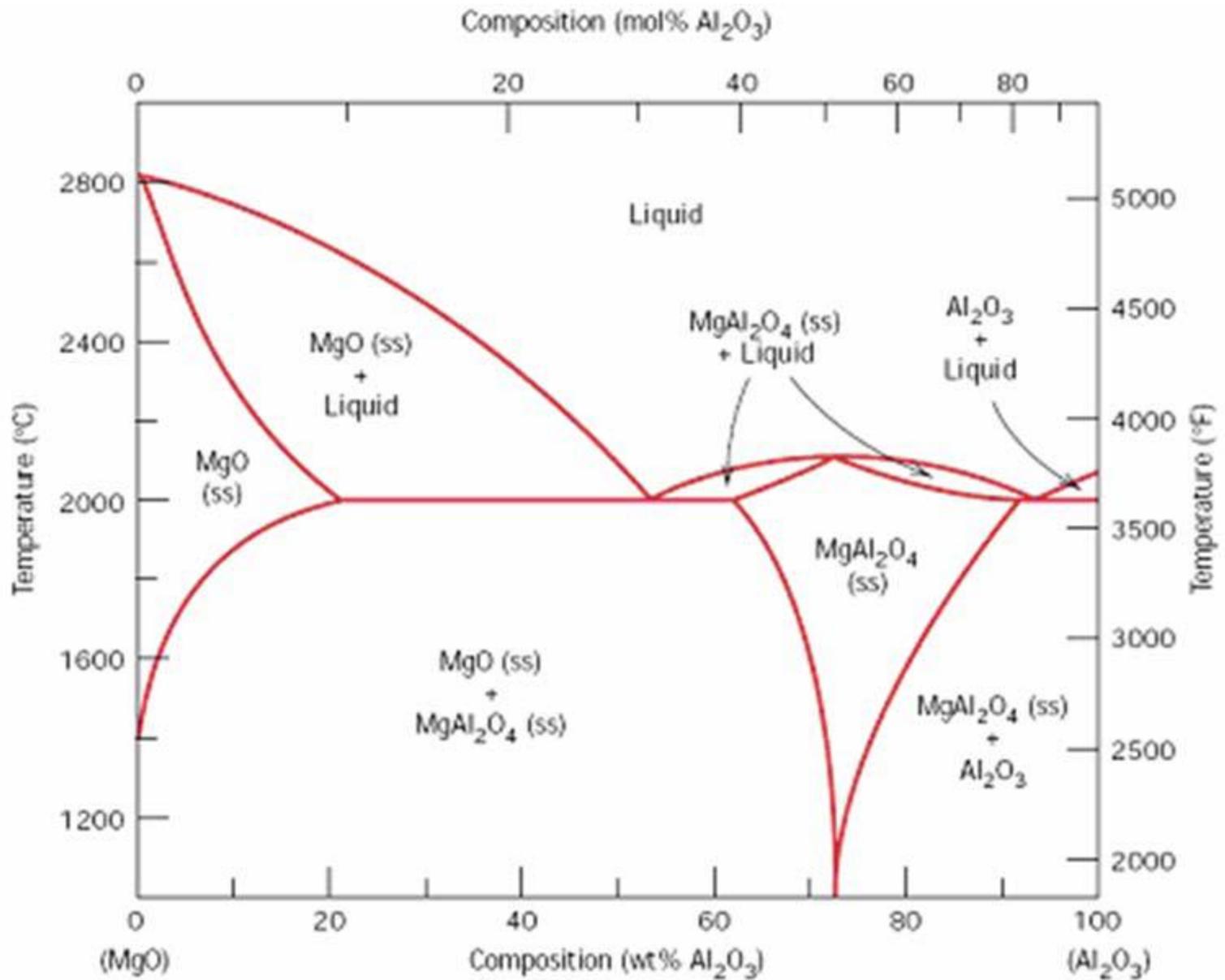
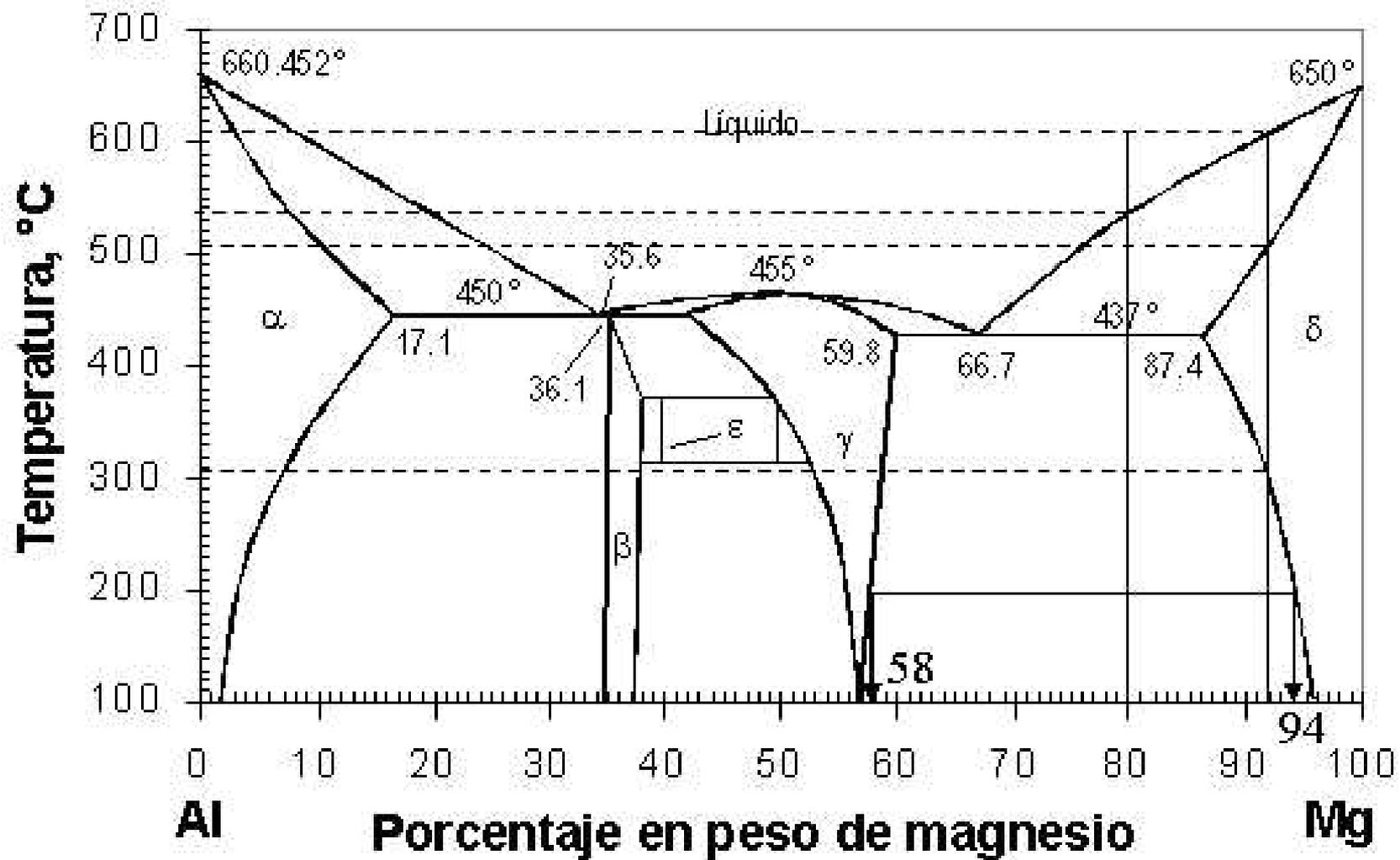
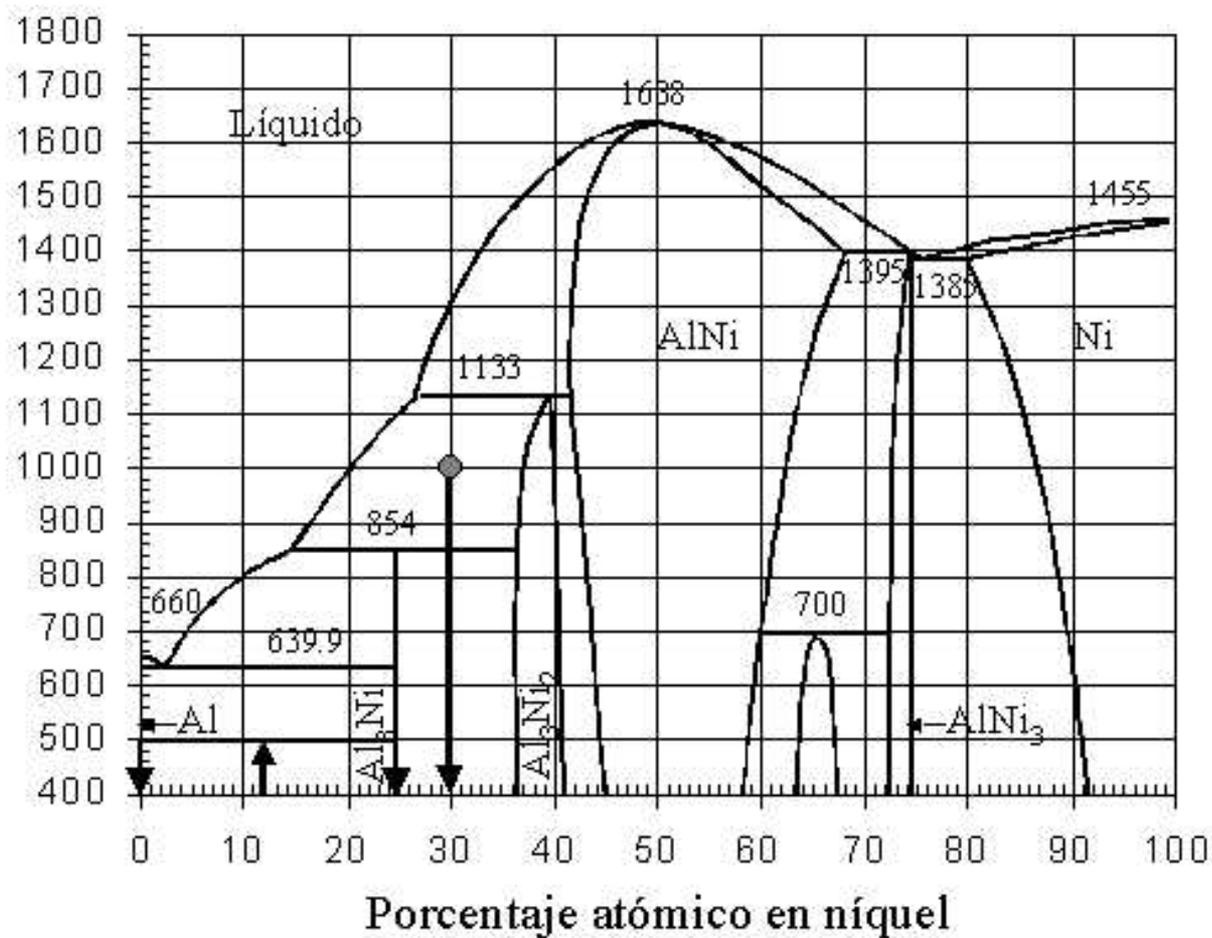
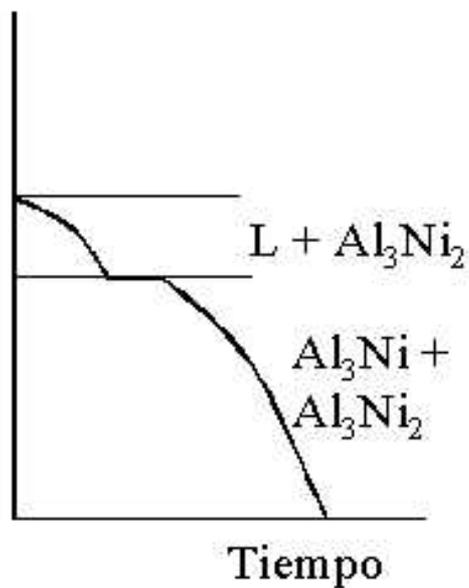
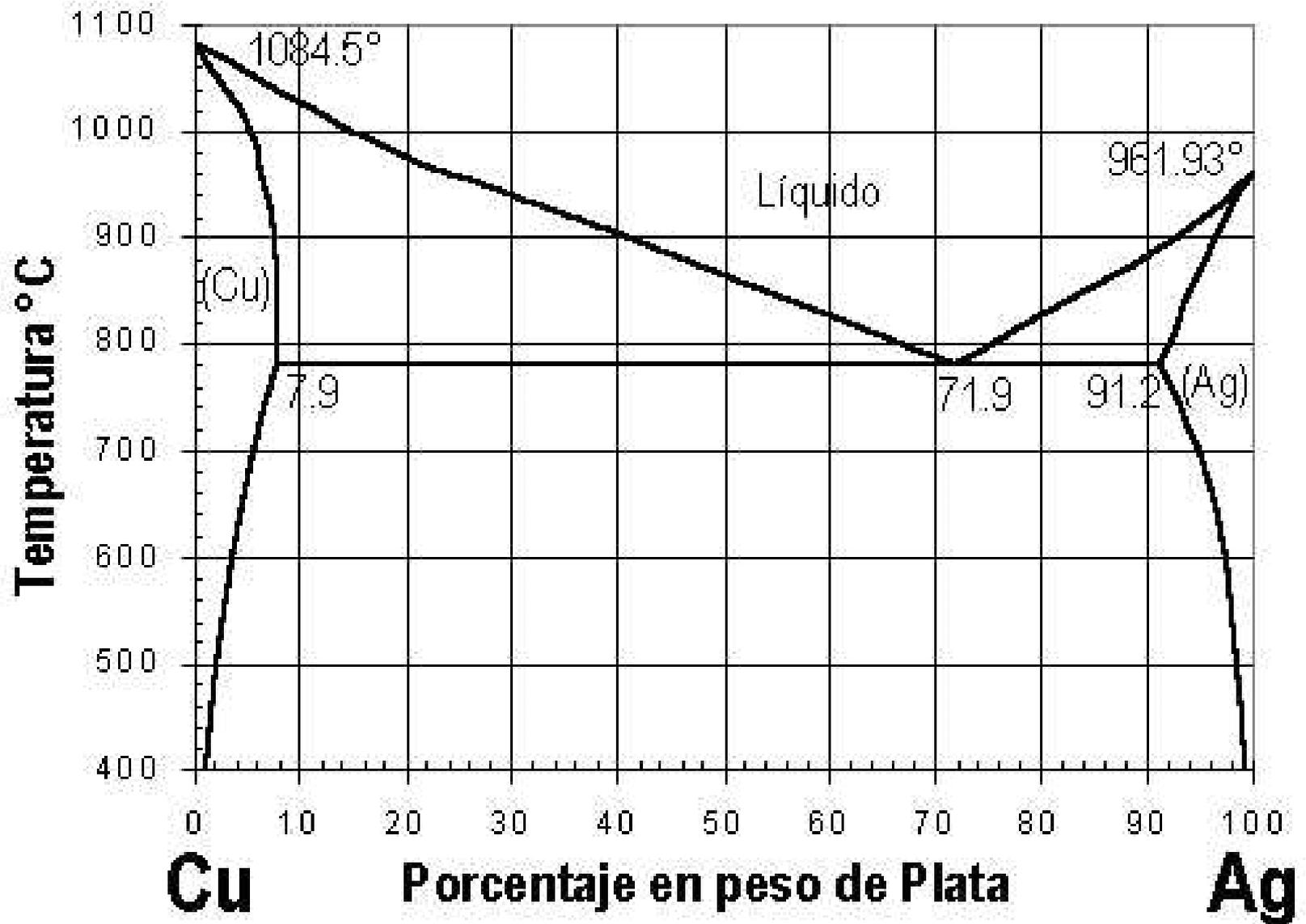
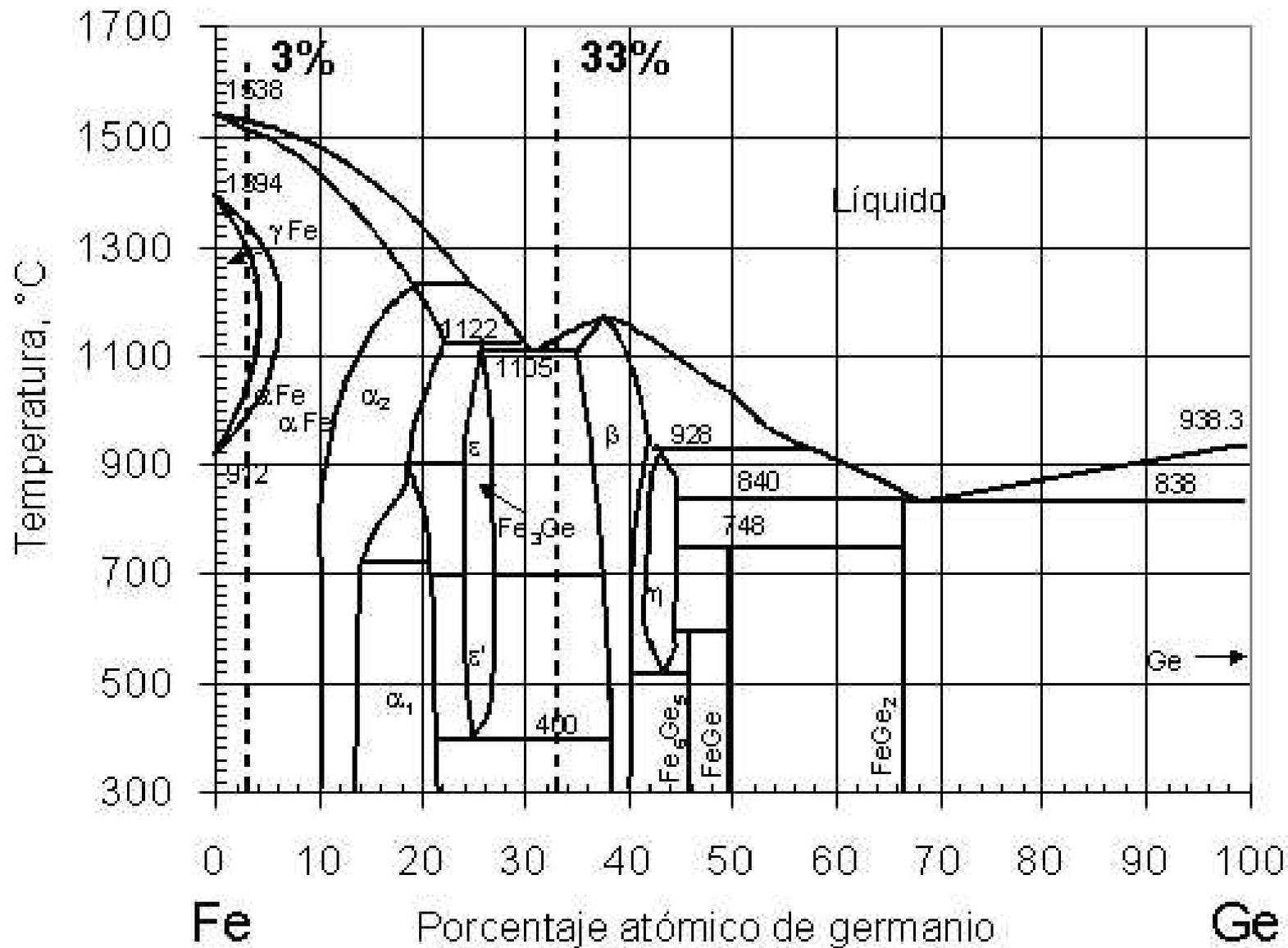


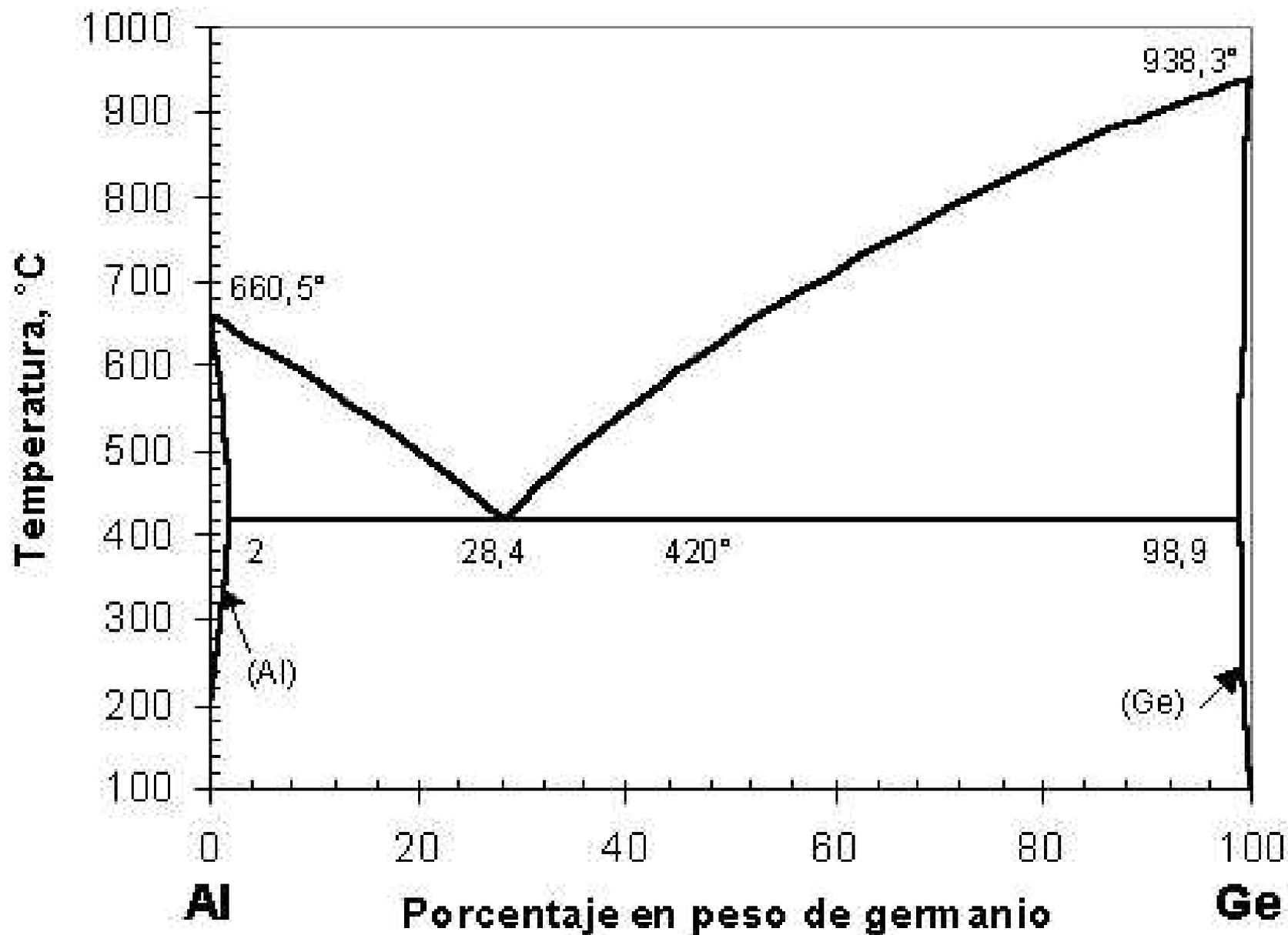
Diagrama de fases MgO – Al₂O₃

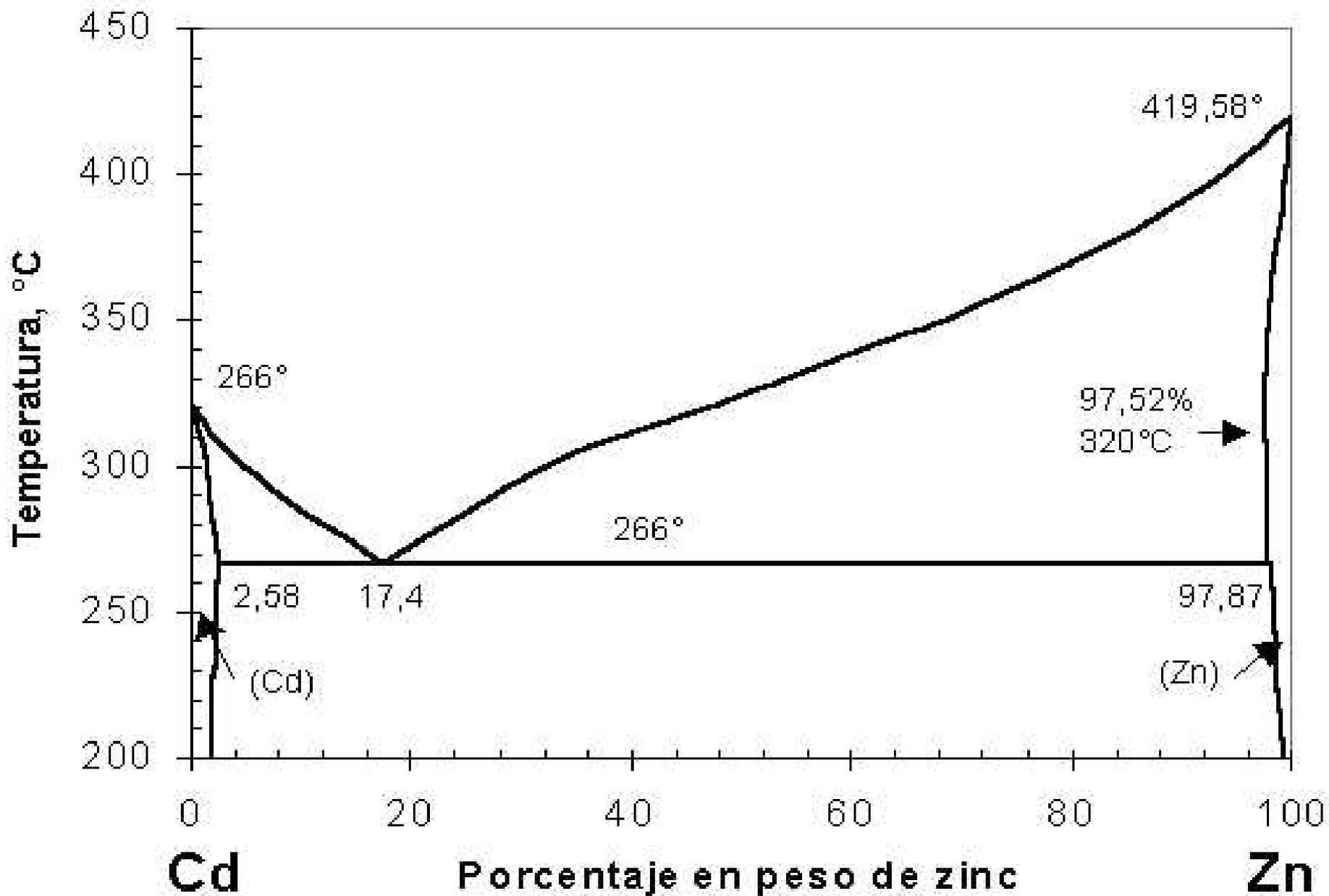


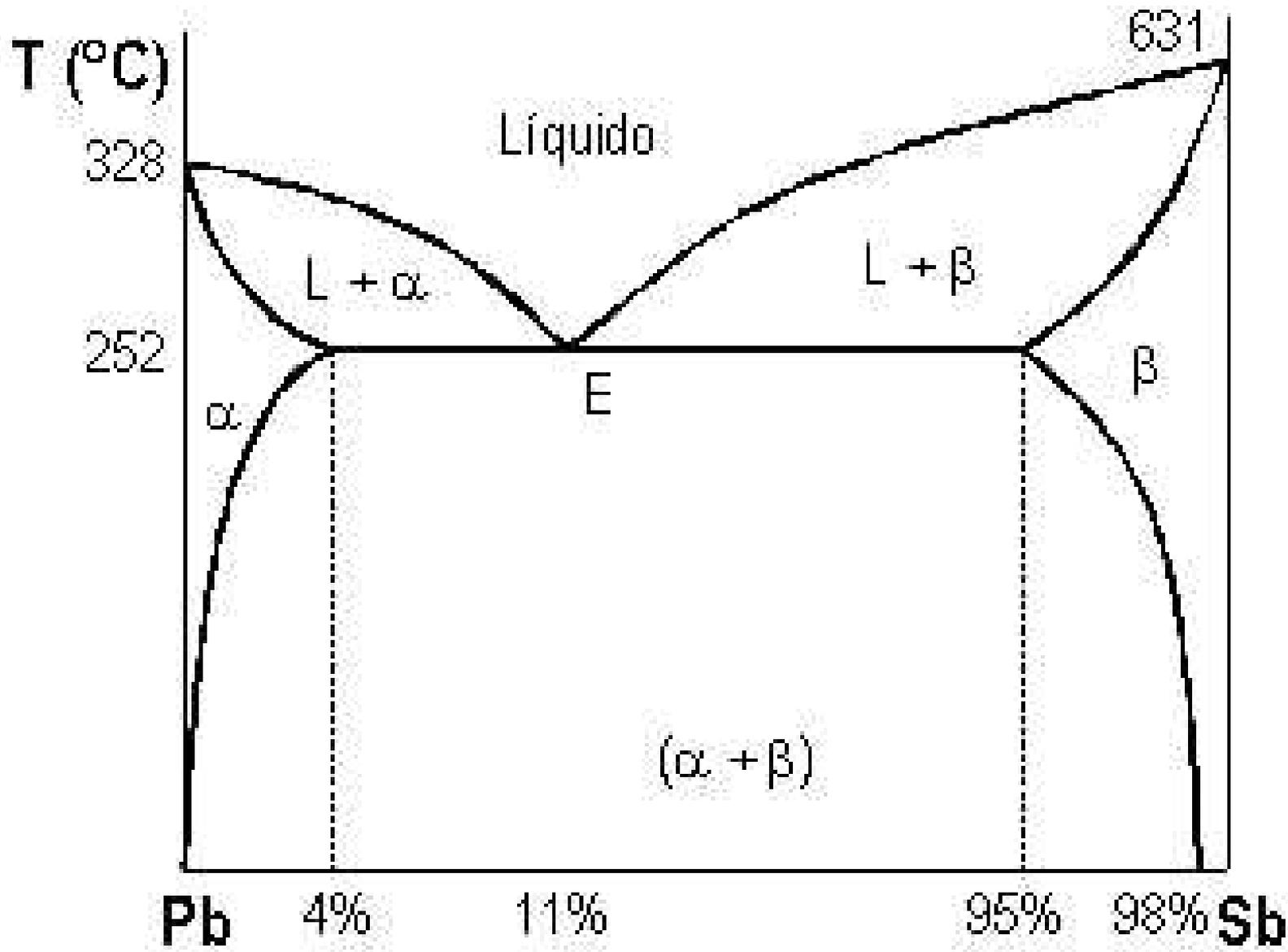












Comportamiento de las aleaciones binarias

Invariant reaction	Phase reaction	Phase diagram
<p>Eutectic (melting point below components)</p>	$L \longrightarrow \alpha(s) + \beta(s)$ <p>cooling</p>	
<p>Peritectic</p>	$\alpha(s) + L \longrightarrow \beta(s)$ <p>cooling</p>	
<p>Eutectoid (single solid phase is transformed into two phases)</p>	$\gamma(s) \longrightarrow \alpha(s) + \beta(s)$ <p>cooling</p>	
<p>Peritectoid</p>	$\alpha(s) + \gamma(s) \longrightarrow \beta(s)$ <p>cooling</p>	

Aleación Ni-Cr

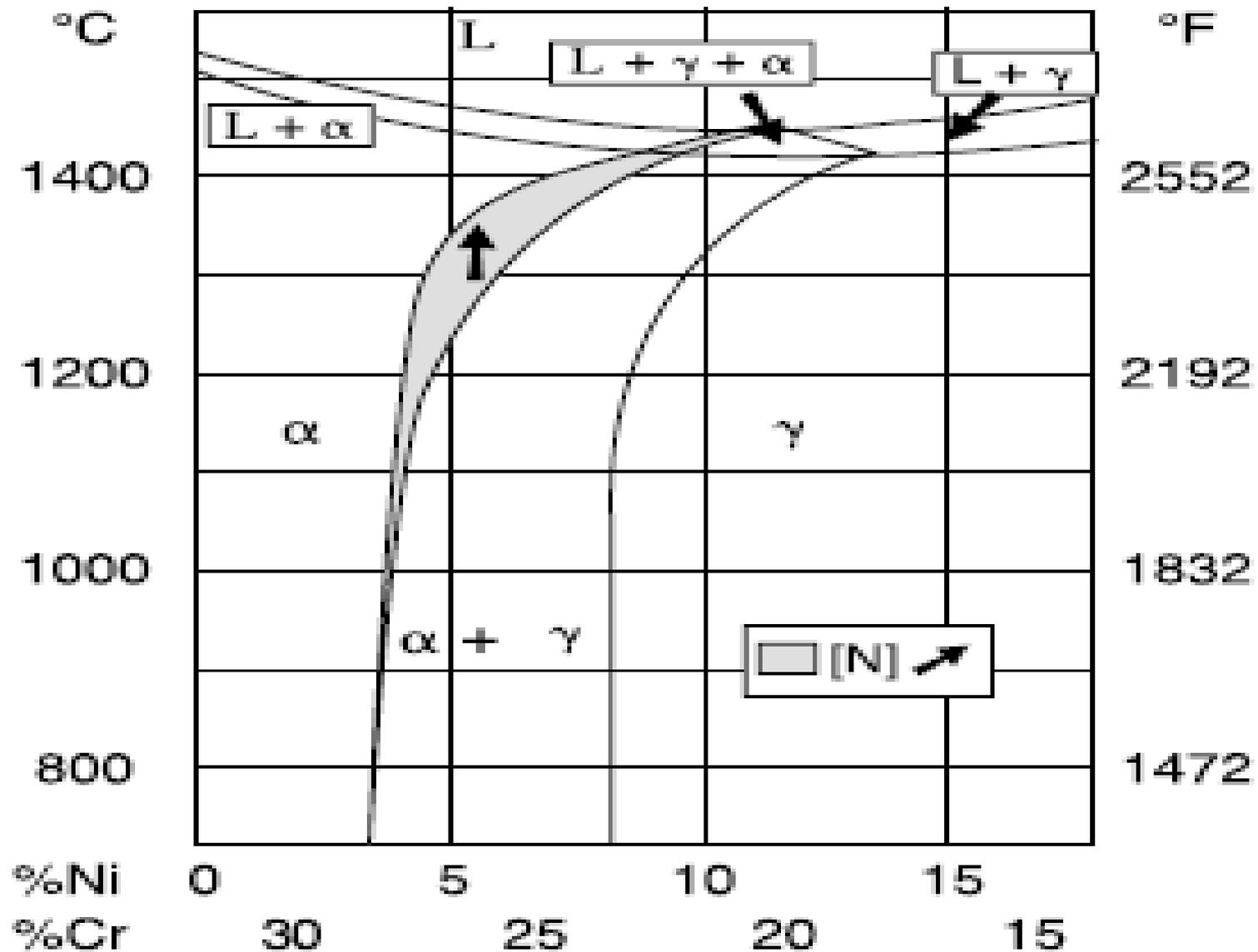
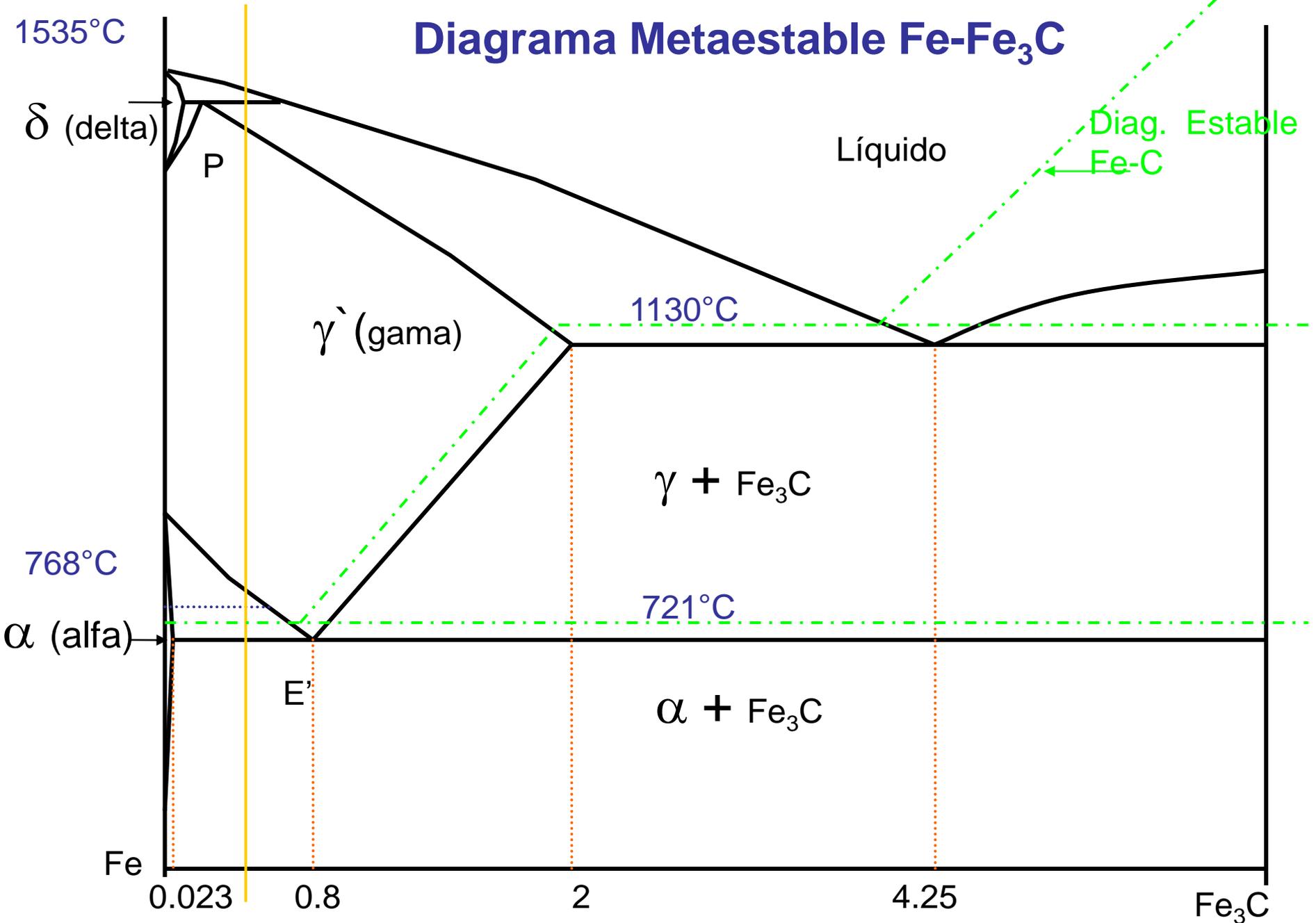


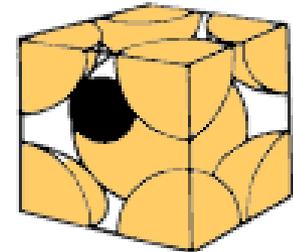
Diagrama Metaestable Fe-Fe₃C



Fases sólidas:

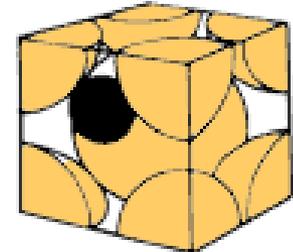
Ferrita α

Es una solución sólida intersticial en una red BCC



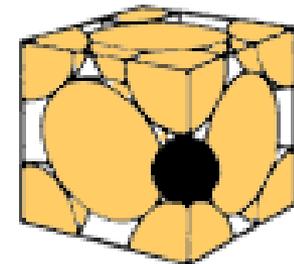
Ferrita δ

Es una solución sólida intersticial en una red BCC

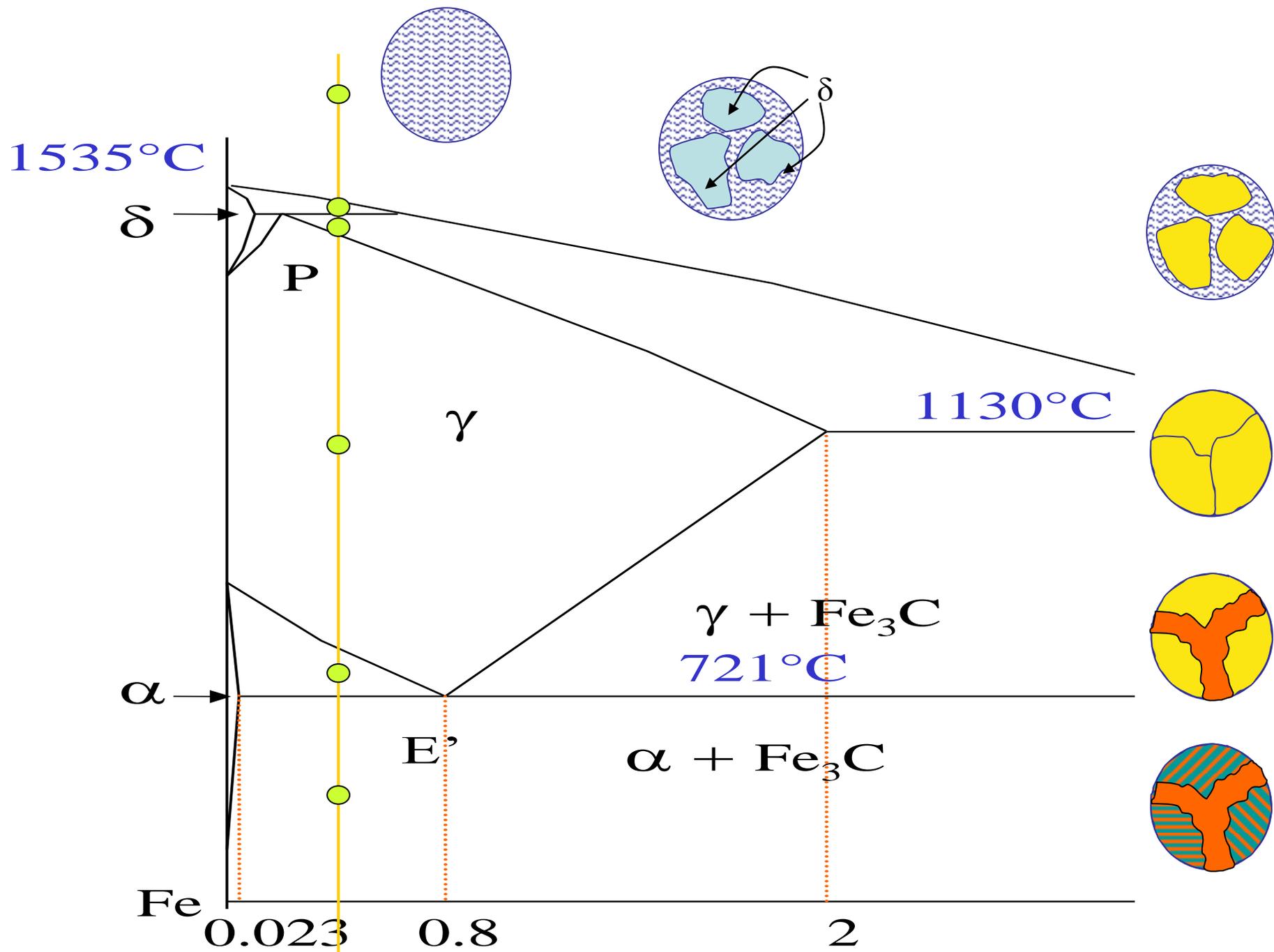


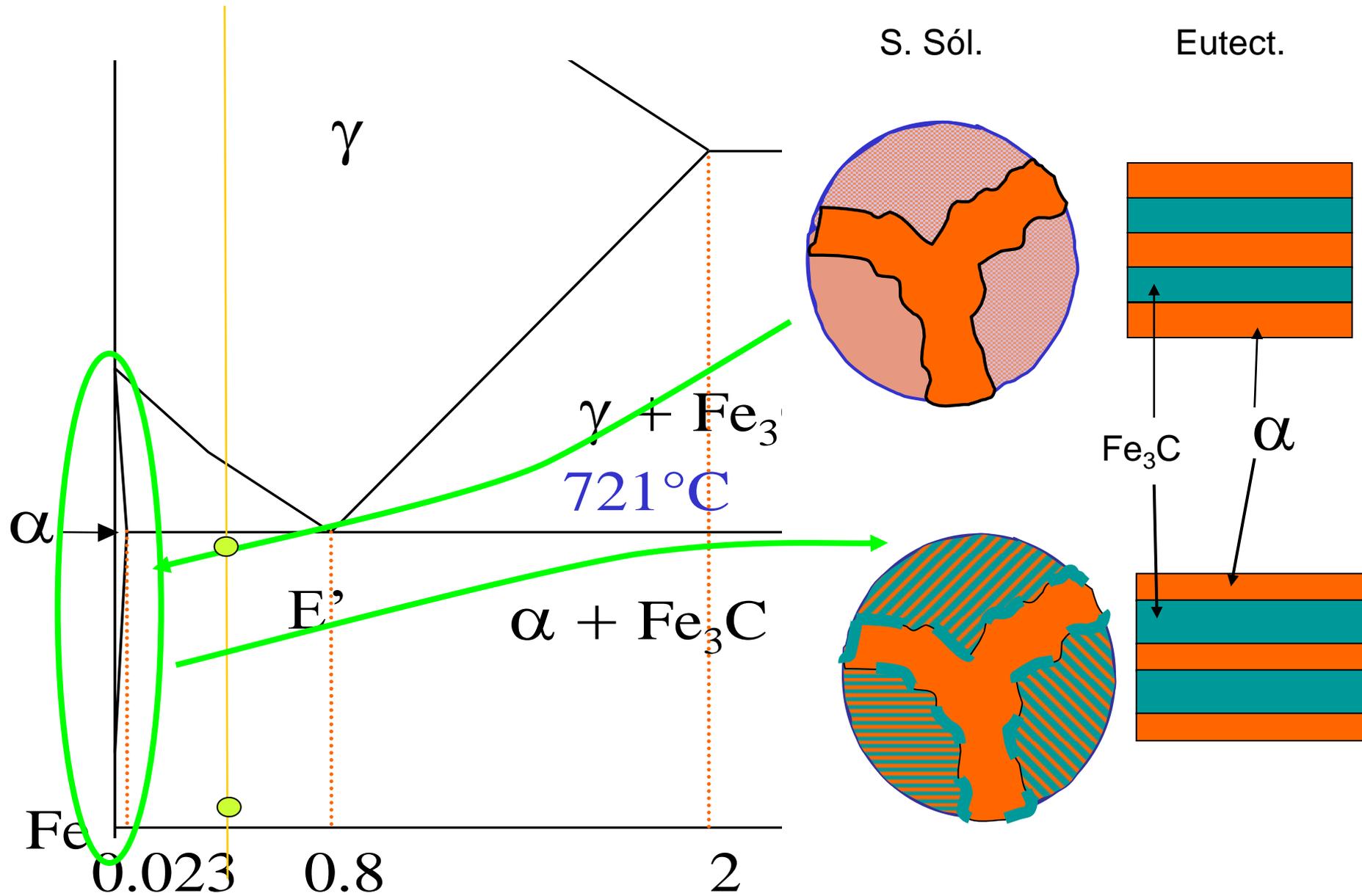
Austenita γ

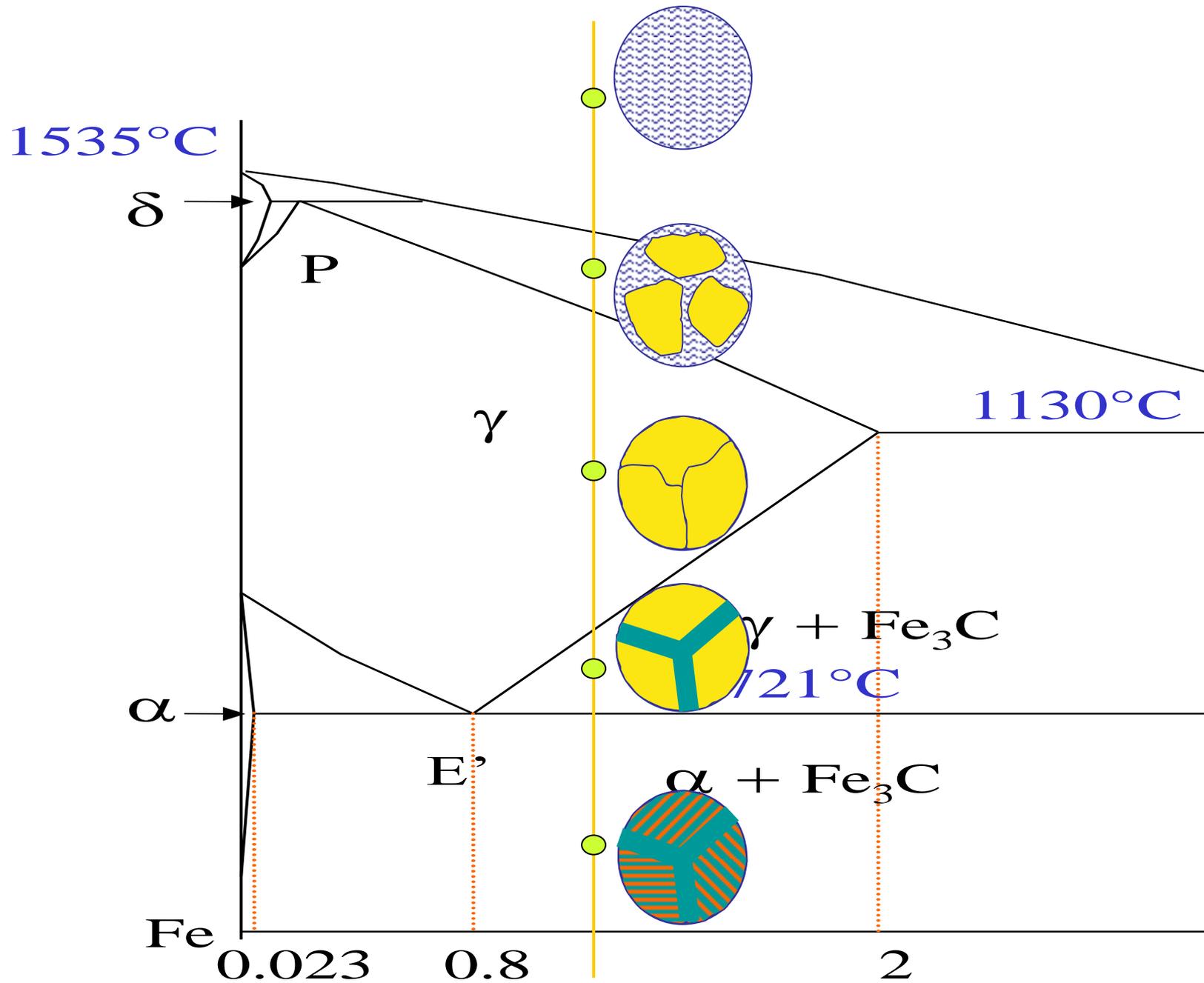
Es una solución sólida intersticial en una red FCC

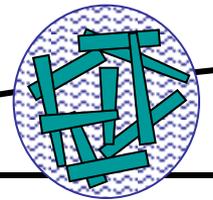
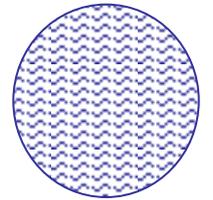
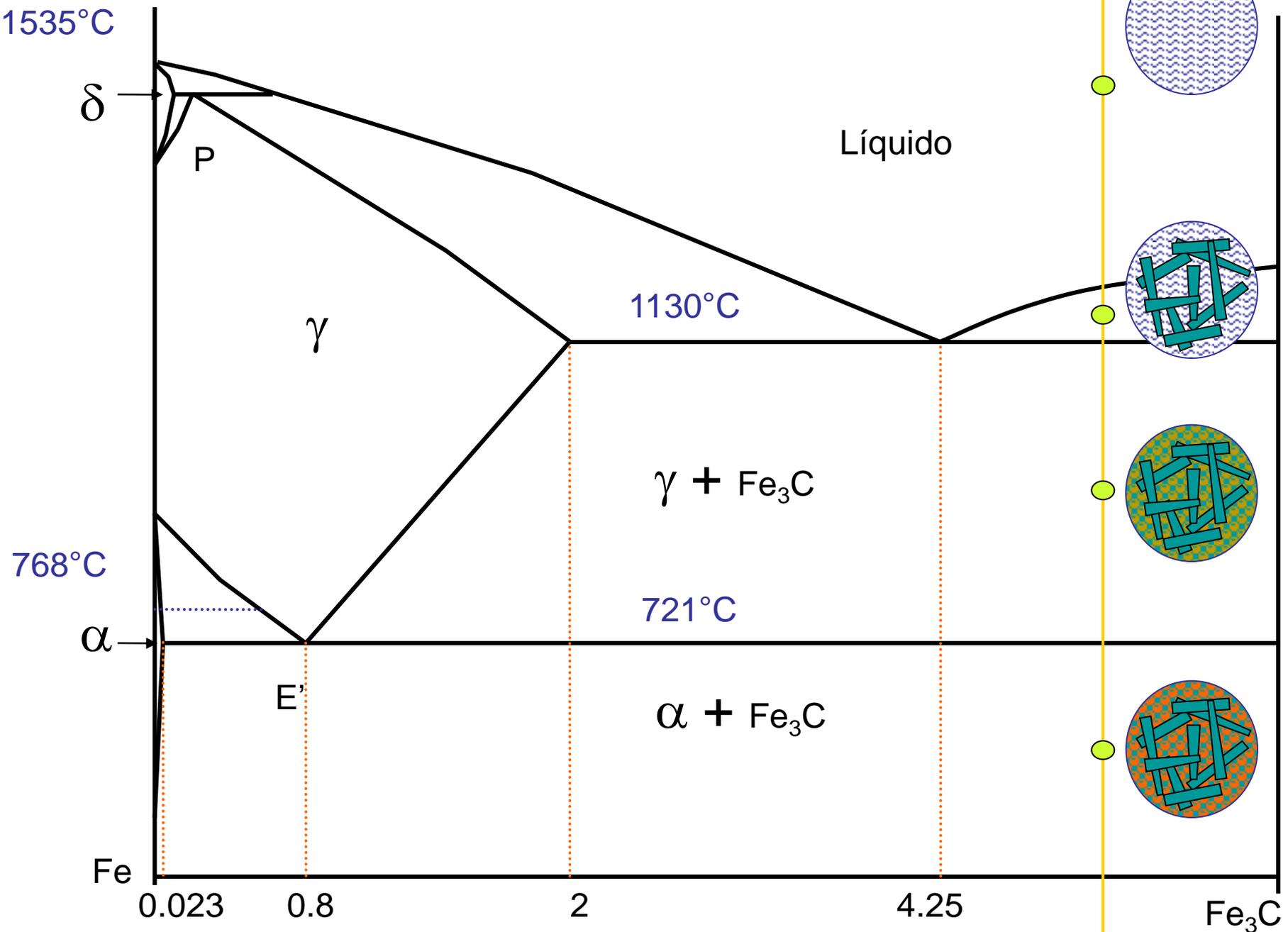


Cementita Fe_3C Es un compuesto intermetálico









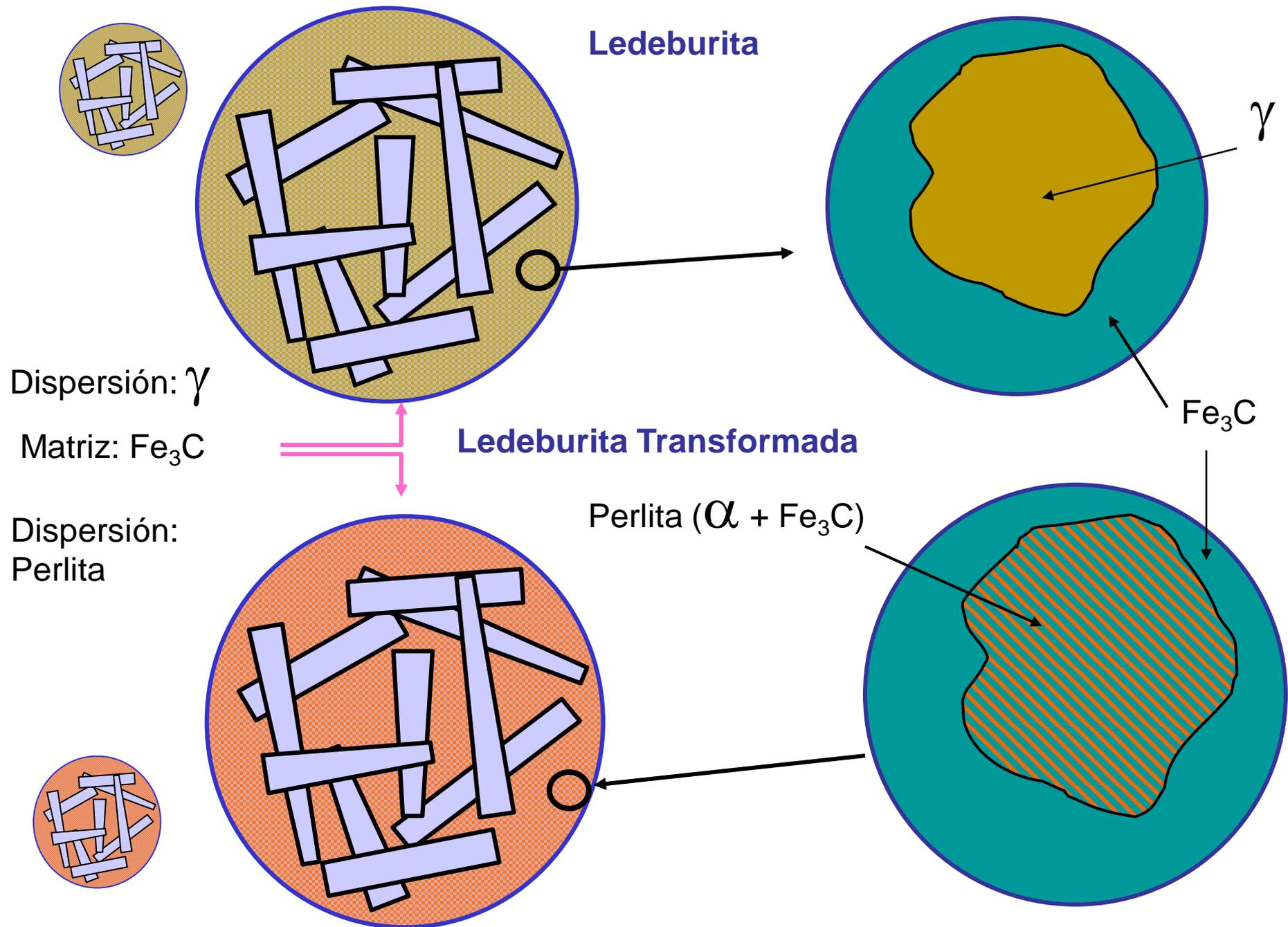
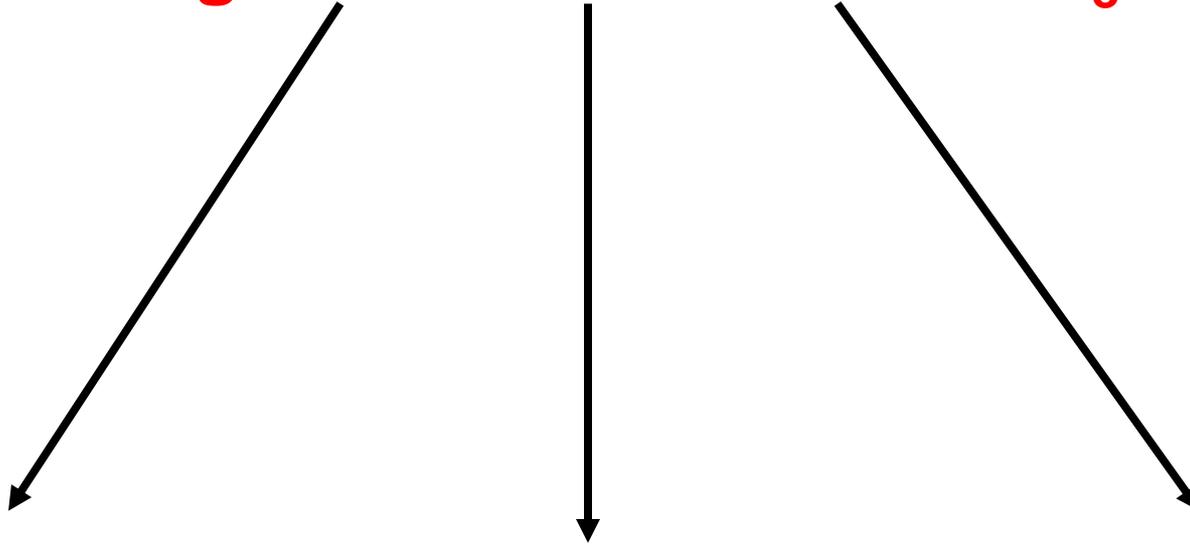


Diagrama Metaestable Fe-Fe₃C



**Componentes
o Elementos**

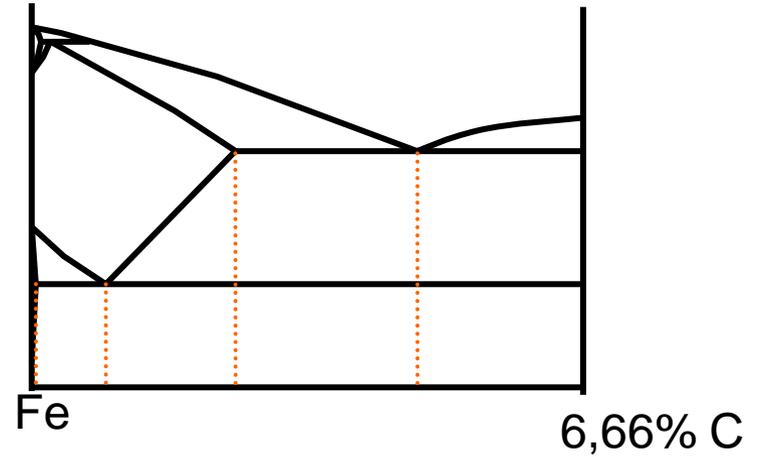
Fases

Constituyentes

Diagrama Metaestable Fe-Fe₃C

Componentes
o Elementos:

Fe
C



Fases:

γ
 δ
 α
Fe₃C

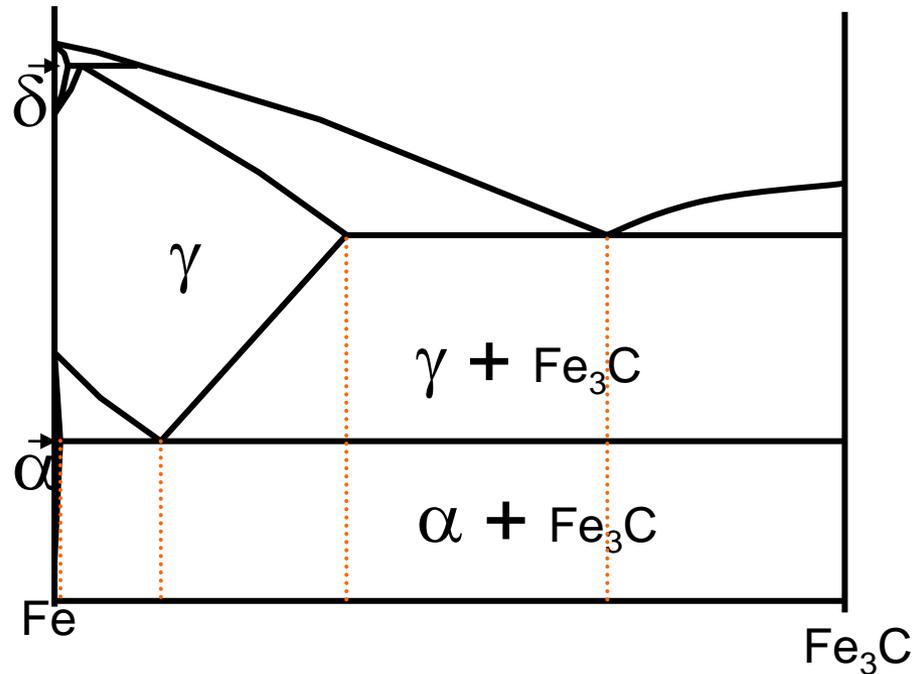


Diagrama Metaestable Fe-Fe₃C

Constituyentes:

(nos dan una idea de cómo están entremezcladas las fases; causa de las propiedades mecánicas)

γ (delta)

δ (gama)

α (alfa)

Fe₃C

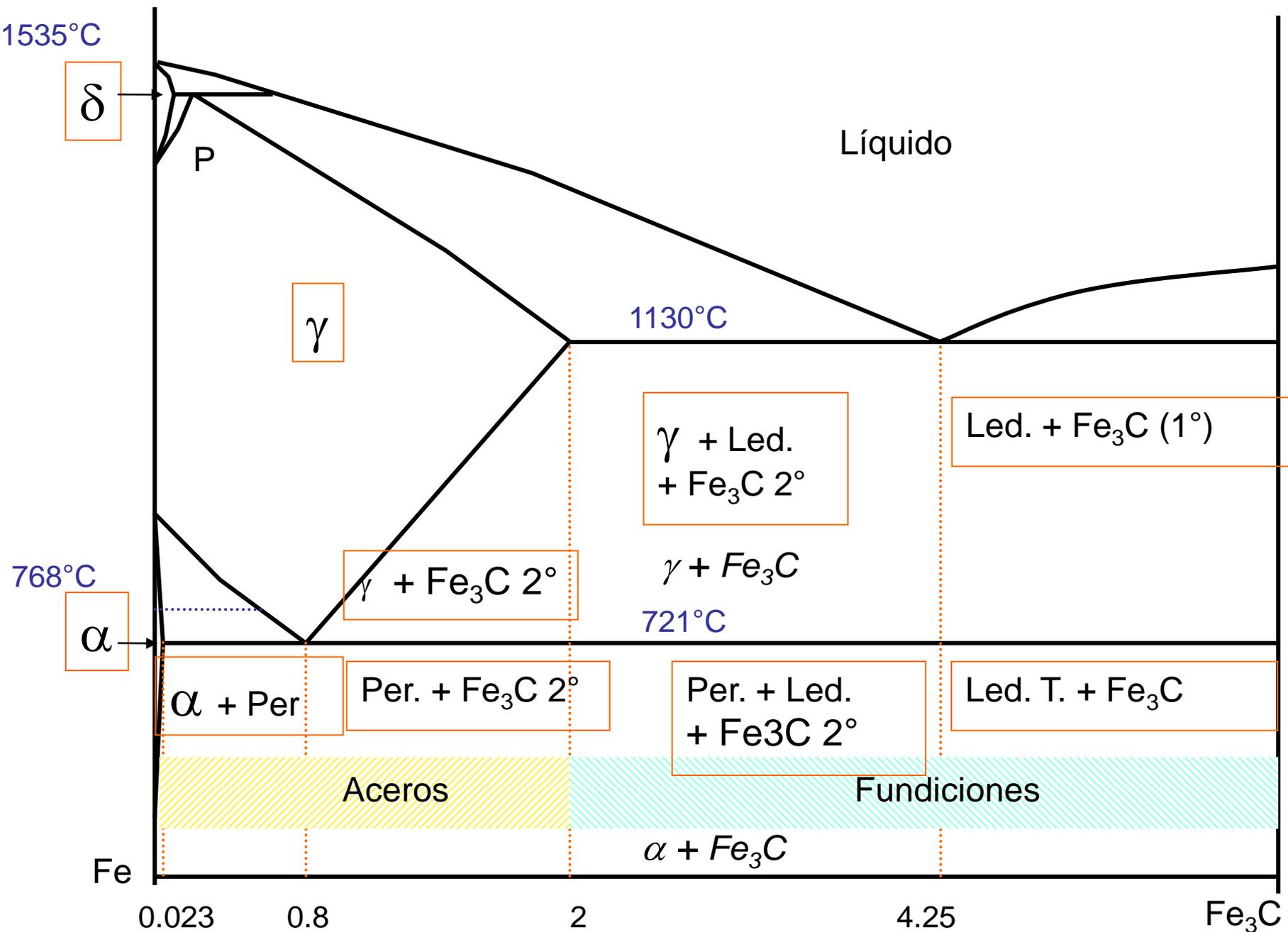
Perlita (α +Fe₃C)

Ledeburita (γ +Fe₃C)

Ledeburita (α +Fe₃C)
Transformada

Const.
Monofásicos

Const.
Bifásicos



Estructuras Metalográficas

- **De nucleación y crecimiento**

Soluciones Sólidas

Metales puros

- **De tipo eutécticas**

Eutécticos

Eutectoides

- **Compuestos intermetálicos**

- **Martensíticas (2° parte de la materia)**

Diagrama ternario

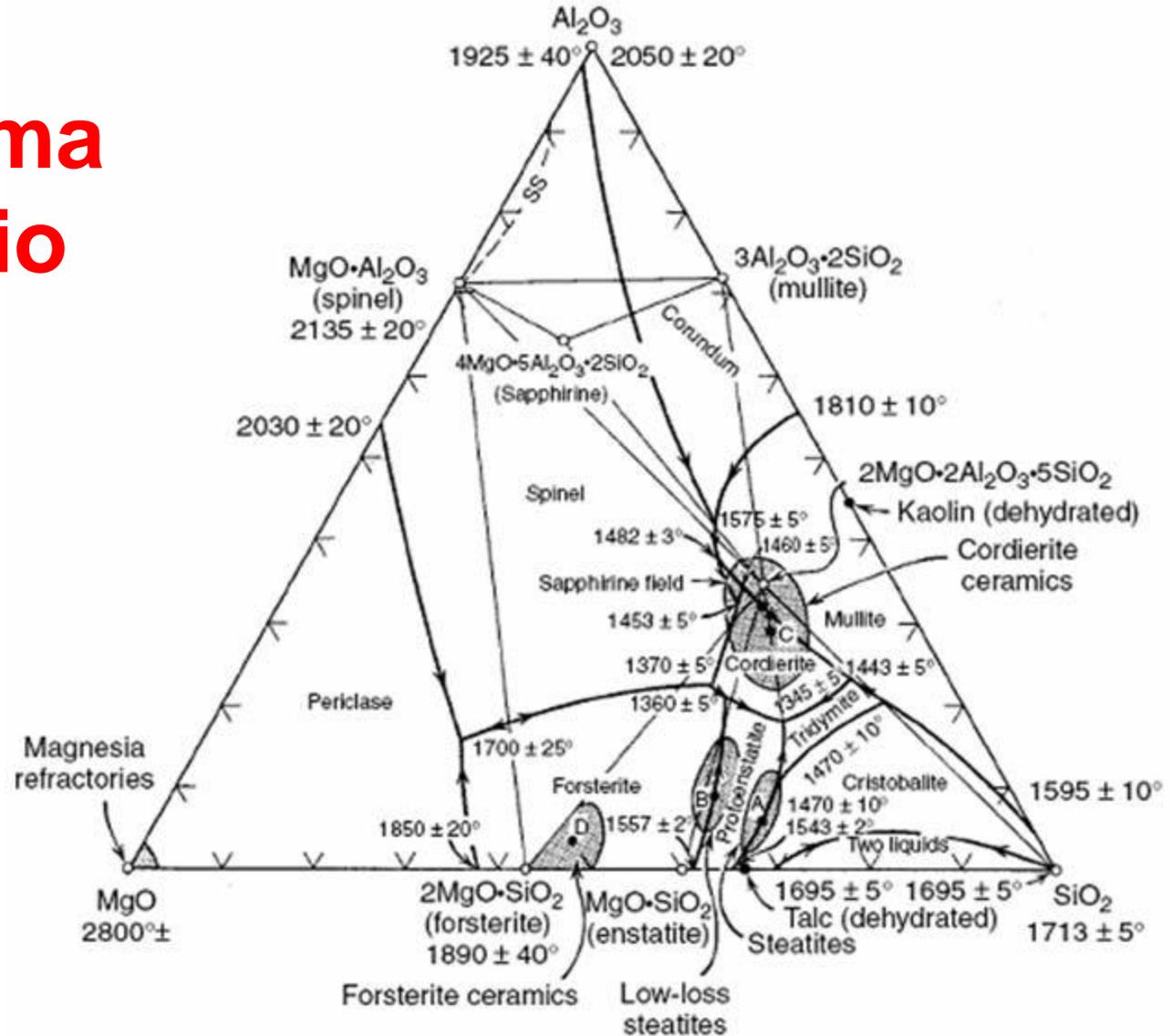
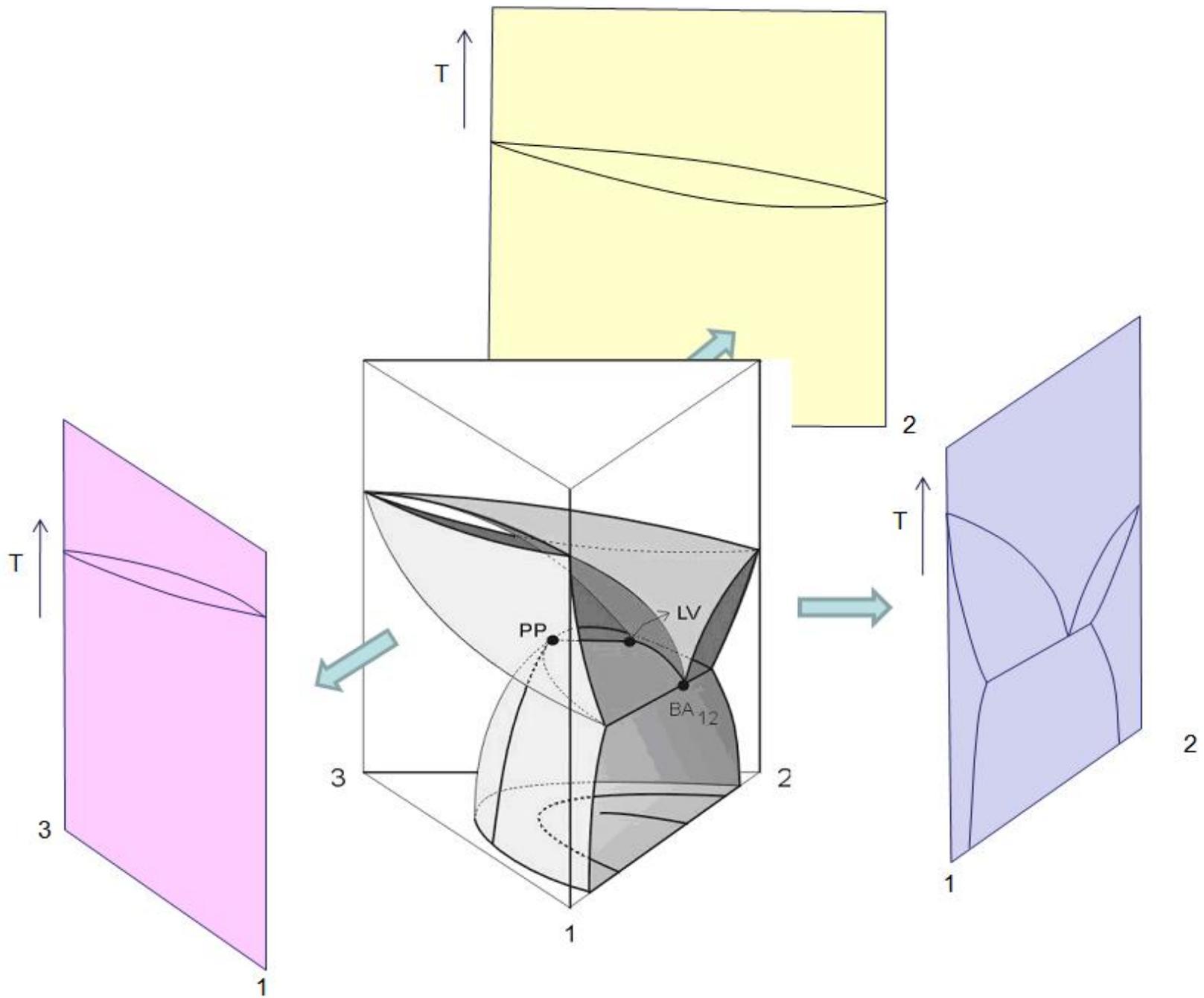


Diagrama de fases SiO_2 – Al_2O_3 – MgO su principal aplicación es en la obtención de refractarios cerámicos



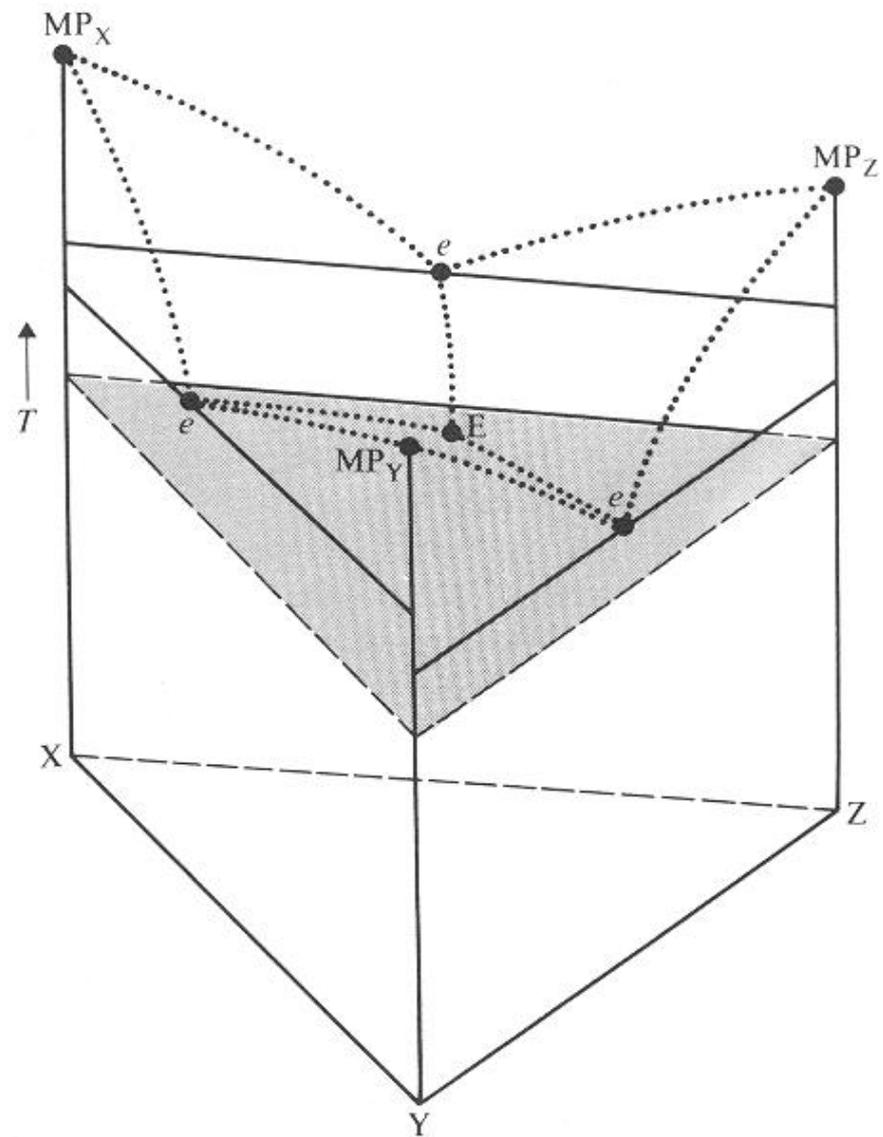
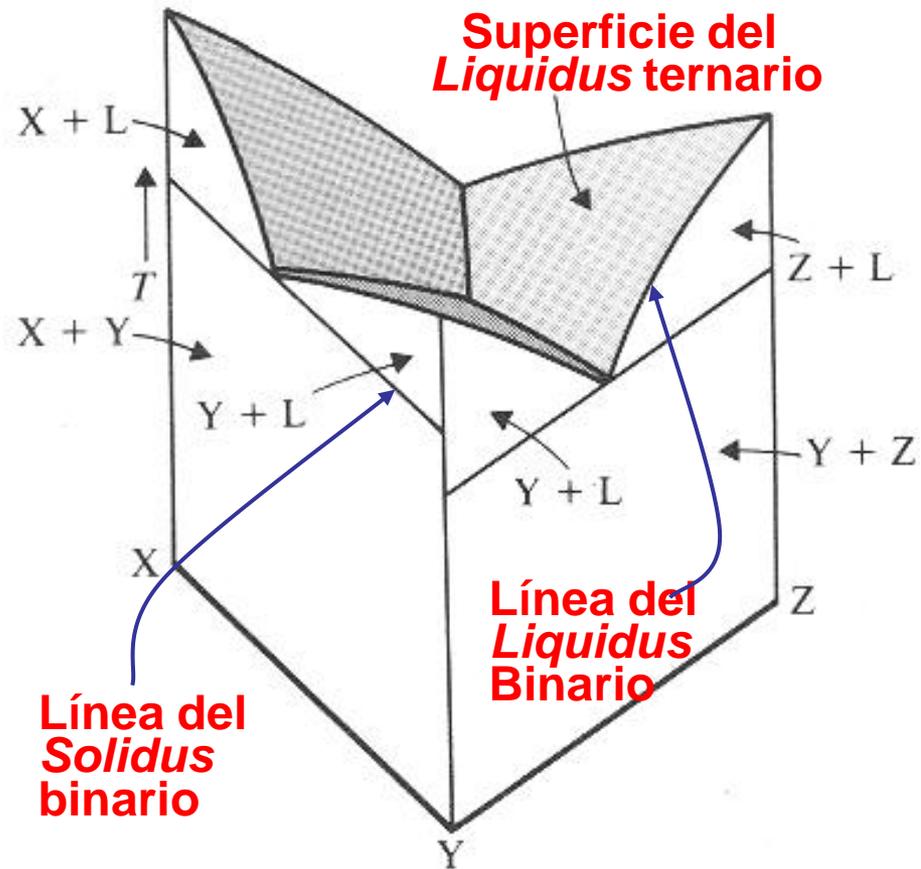
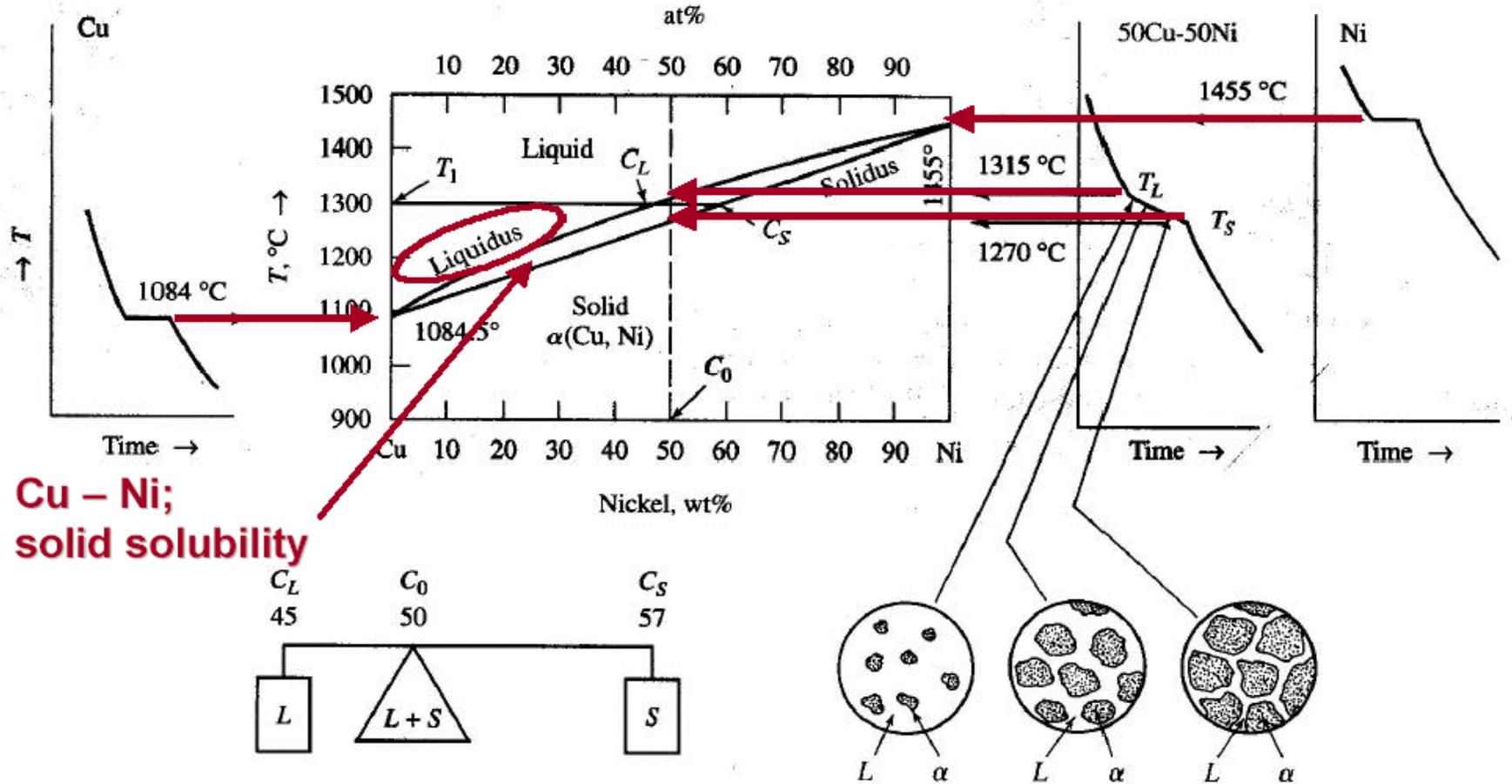


Diagrama de fases Cu-Ni totalmente soluble un metal en el otro



Proyección del análisis térmico para el digrama de fases de la aleación Cu-Ni

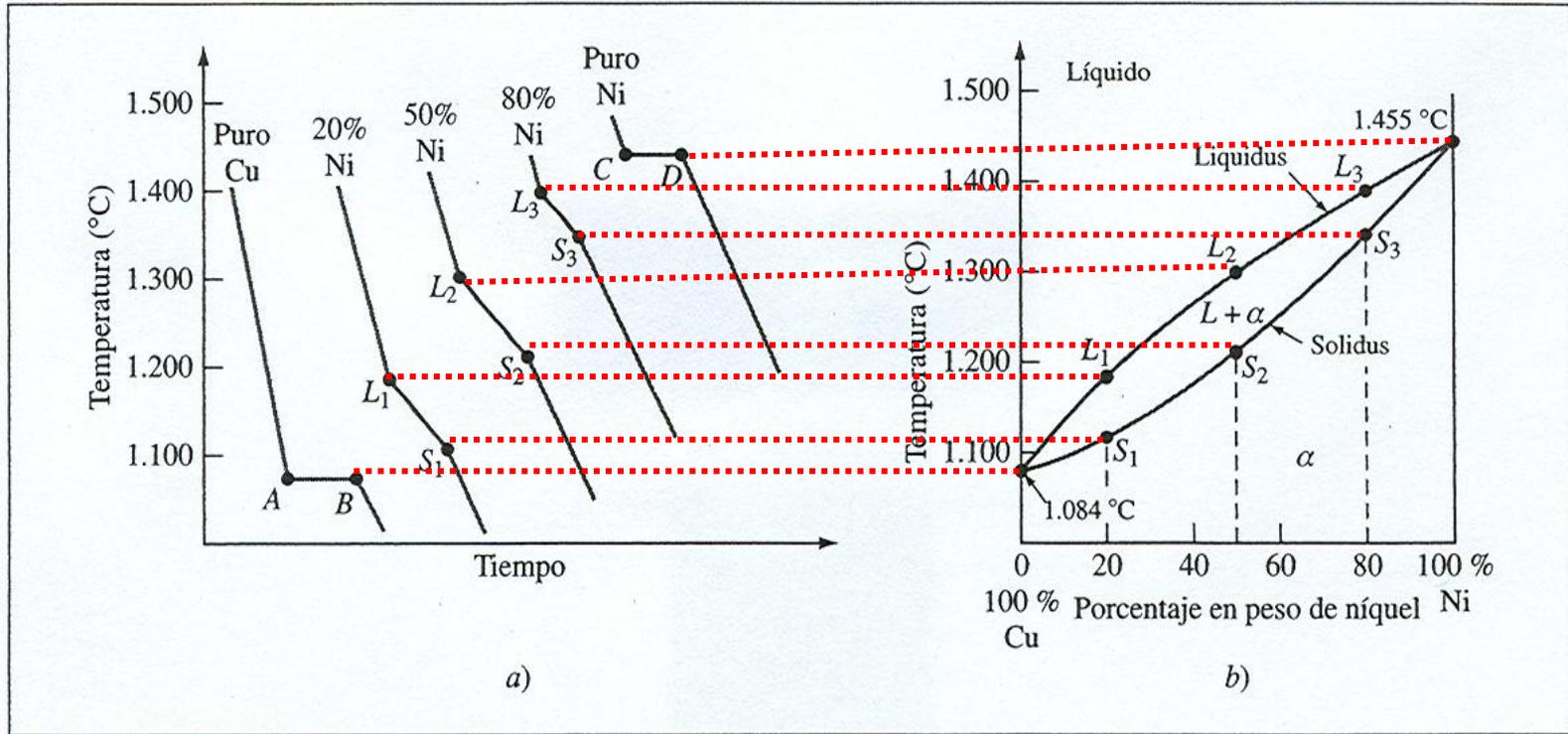
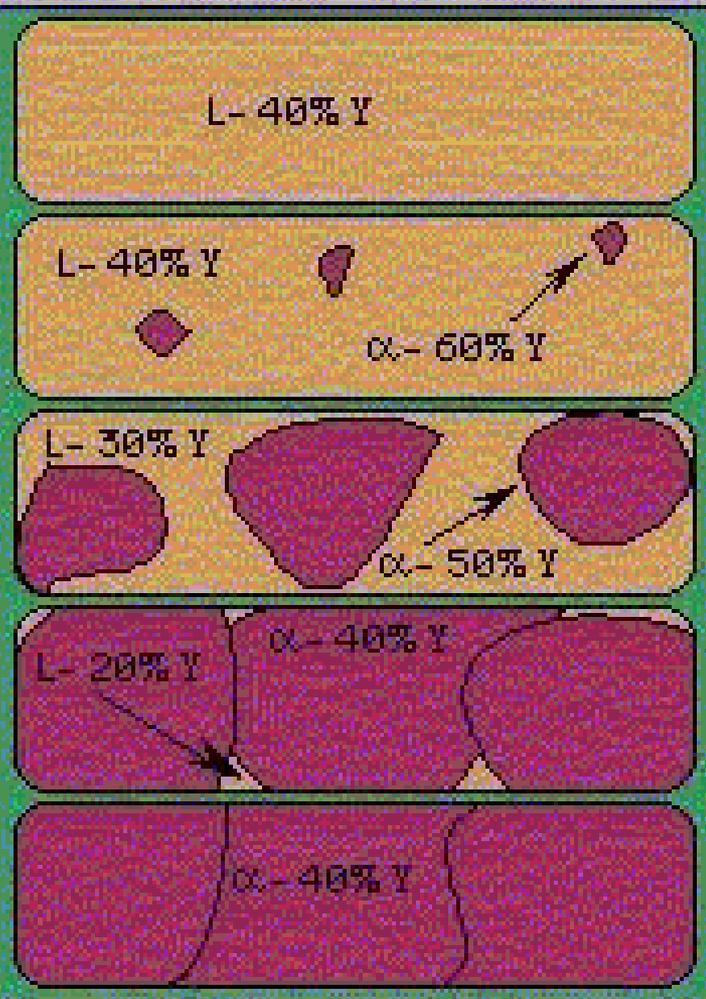
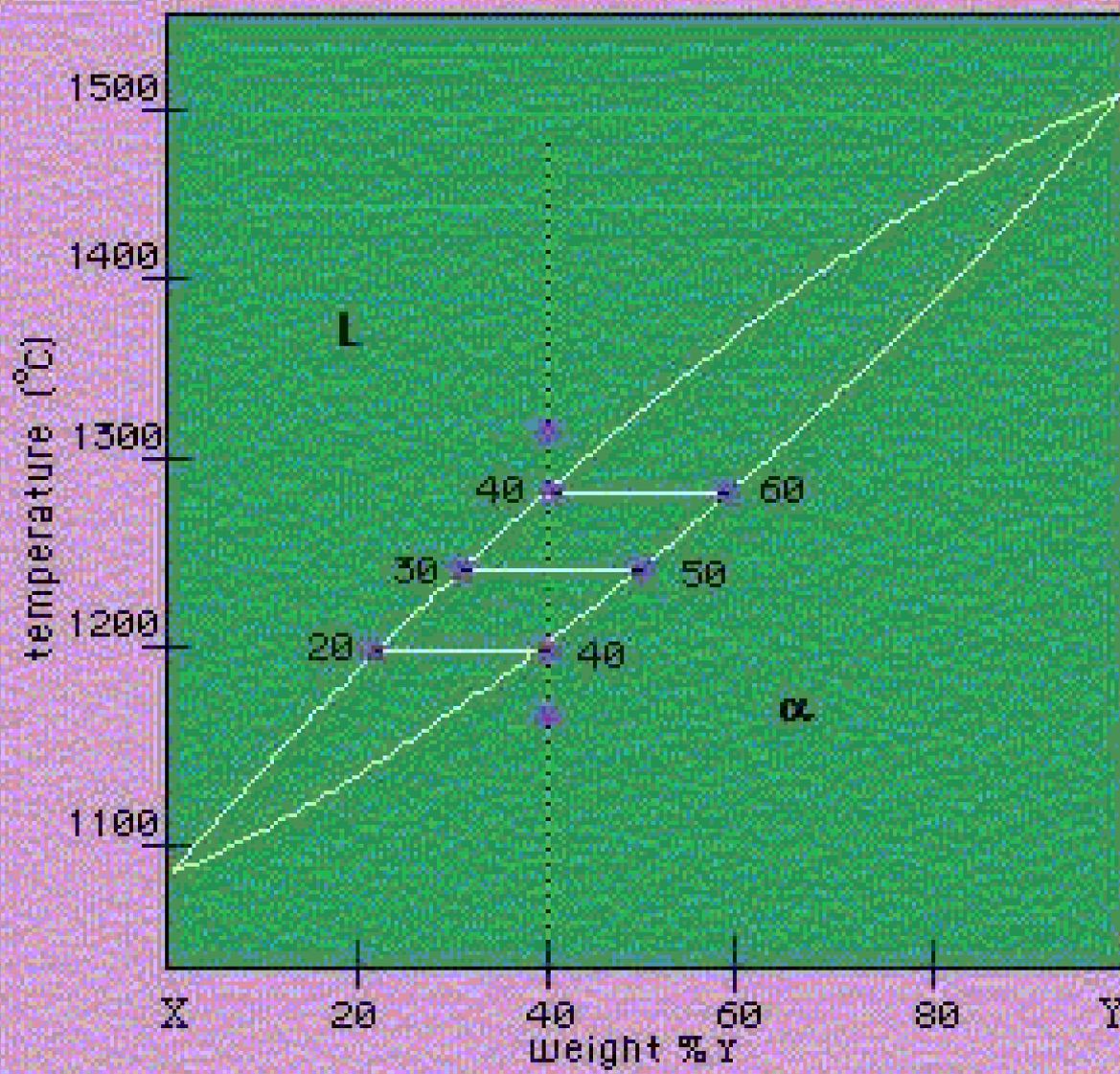
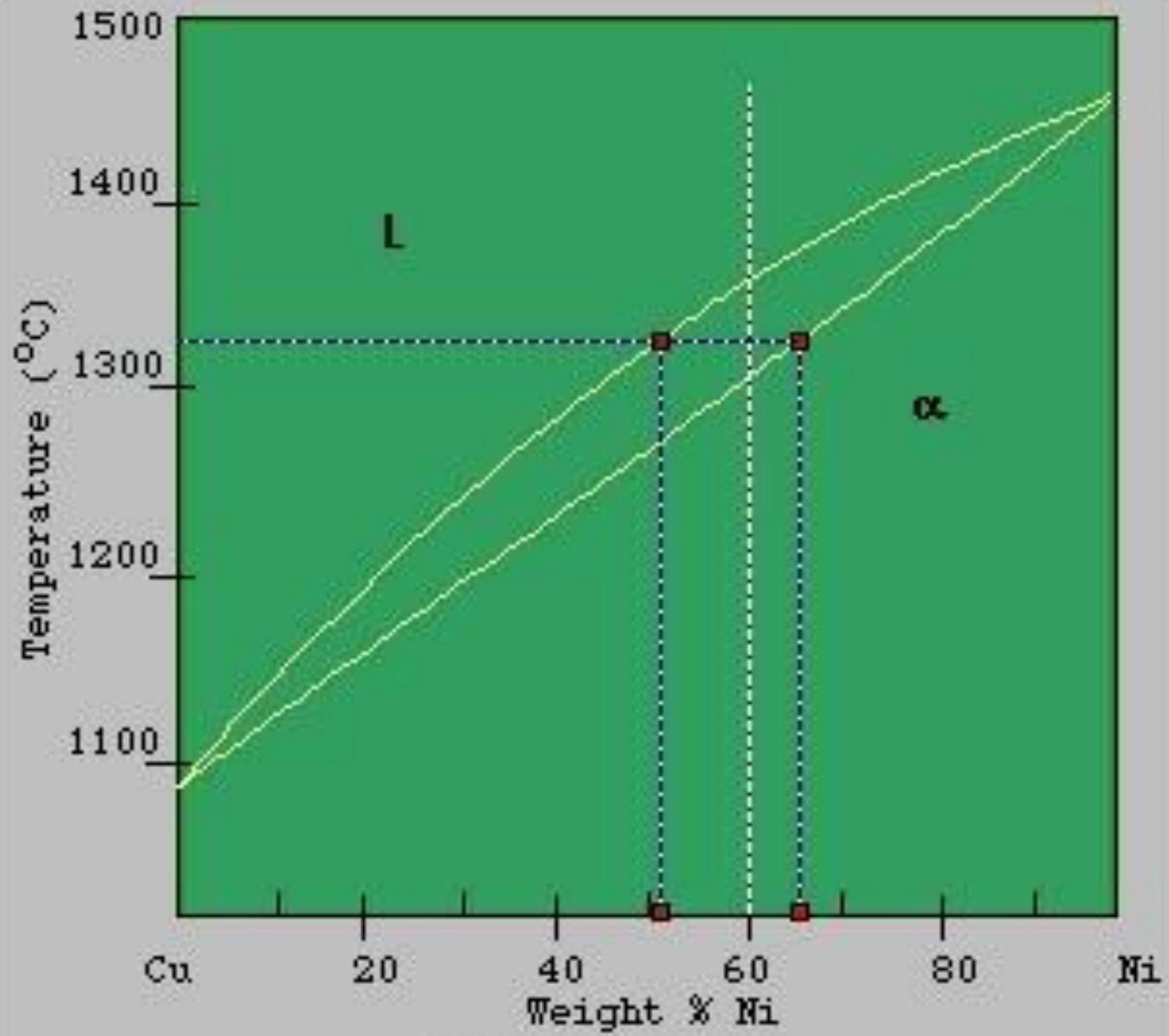


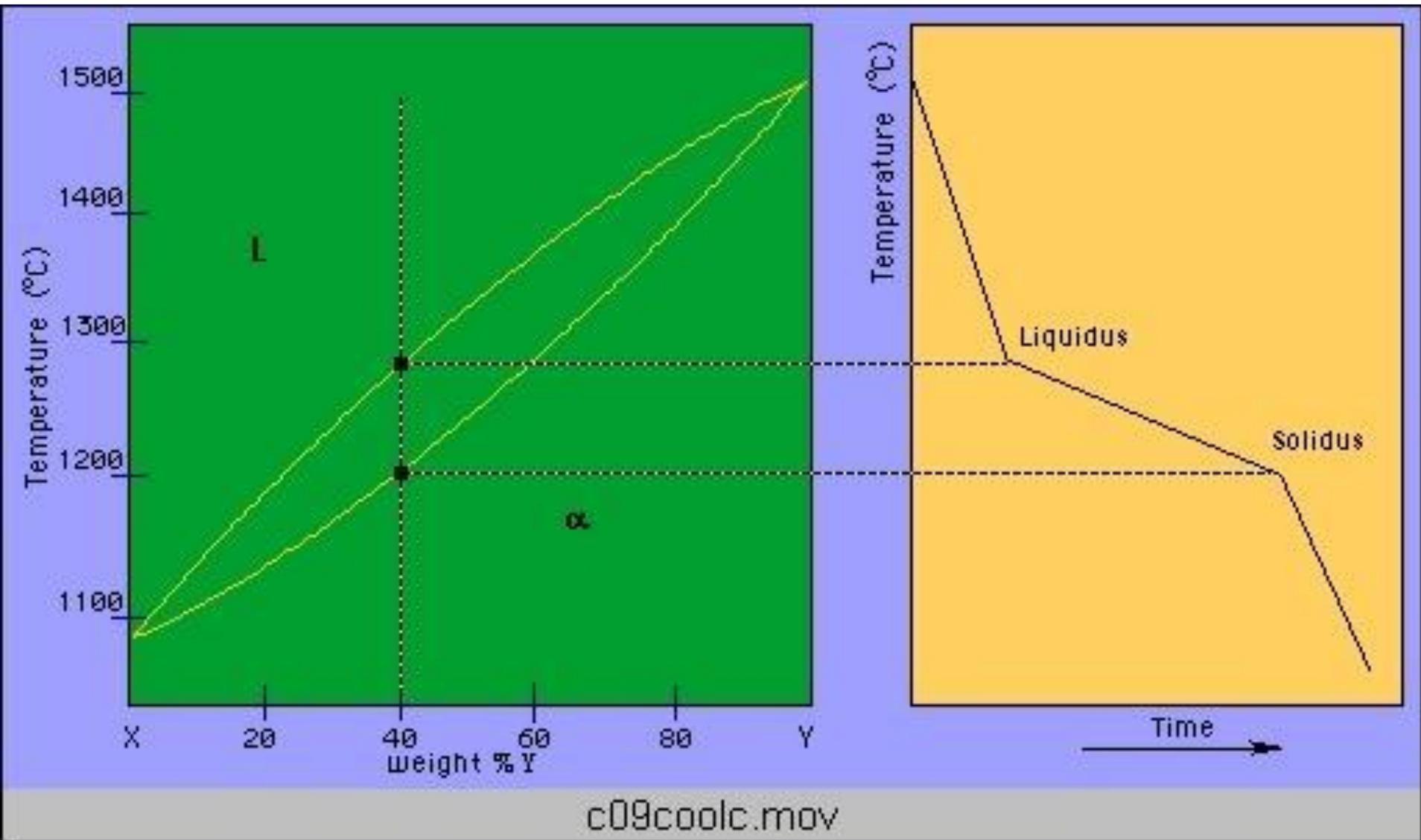
FIGURA 8.4. Construcción del diagrama de fases en equilibrio del Cu-Ni a partir de las curvas de enfriamiento líquido-sólido. a) Curvas de enfriamiento, y b) diagrama de fases en equilibrio.

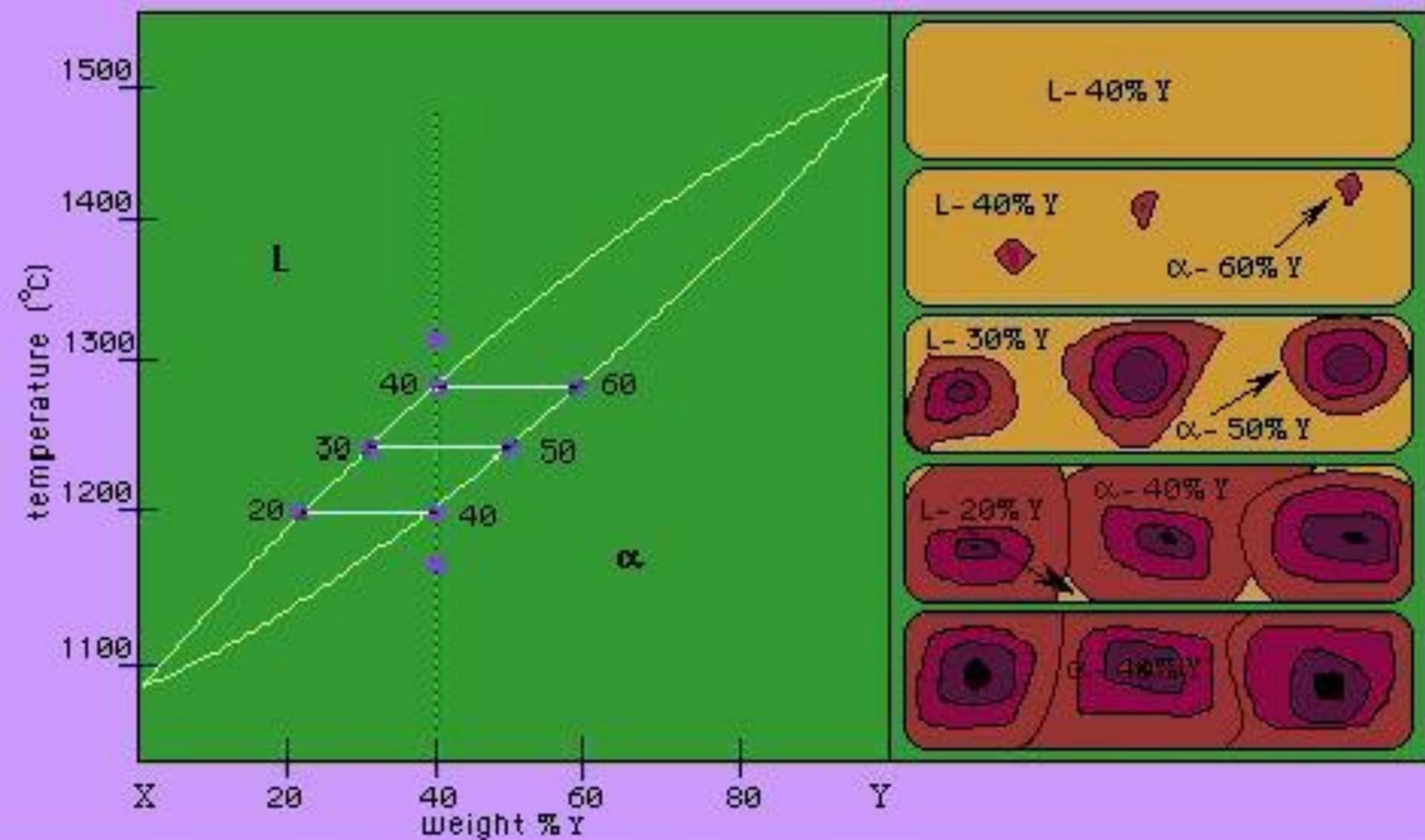


c09solid.mov



c09tryme.mov





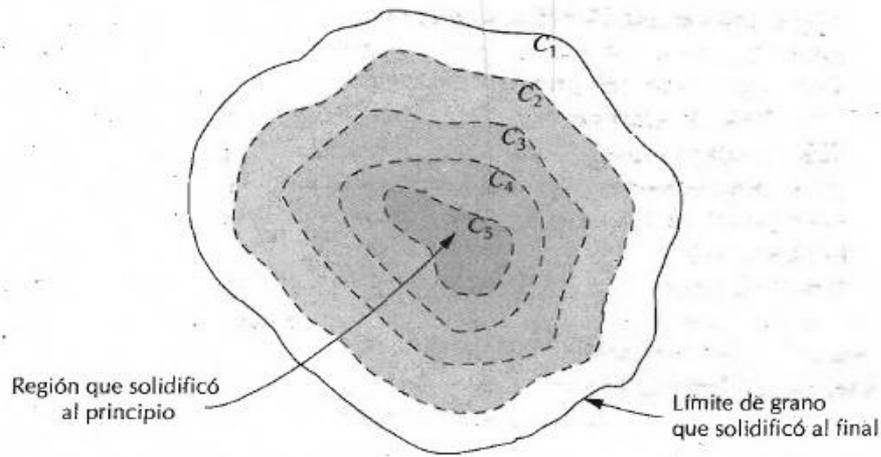


Figura 9.4 Esquema de la segregación en un cristal. En una estructura segregada, se establecen los gradientes de concentración a través de los granos; las líneas discontinuas indican contornos de segregación (C_1 , C_2 , C_3 , etc.).

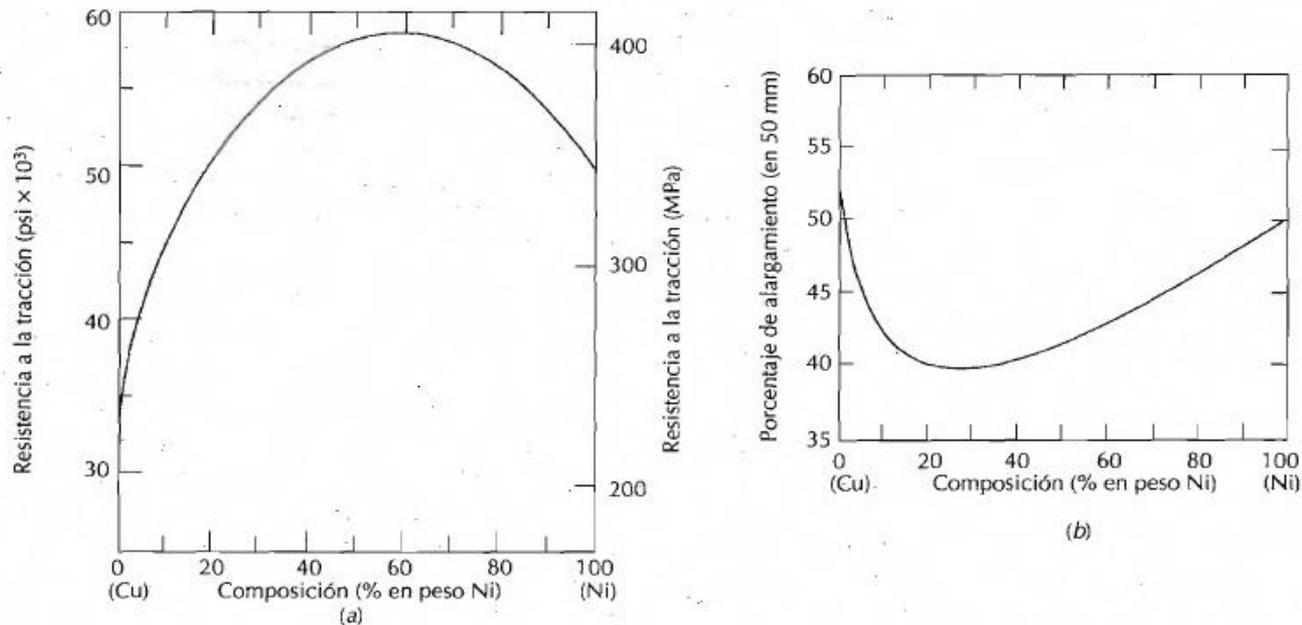


Figura 9.5 Sistema cobre-níquel, (a) resistencia a la tracción frente a composición y (b) ductilidad (%EL) frente a composición. En todas las composiciones de este sistema existe una disolución sólida.

Solución sólida α + solución sólida β

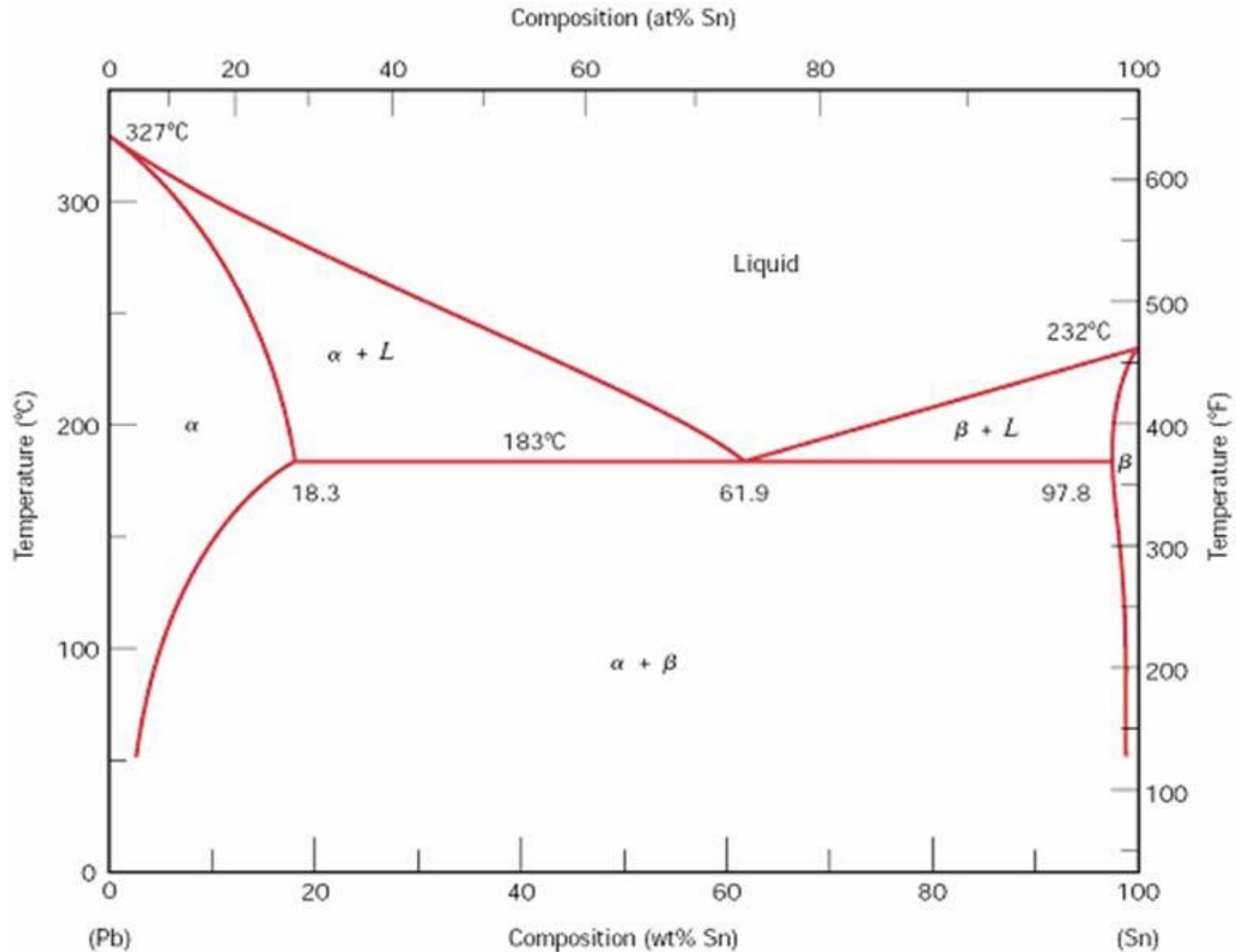
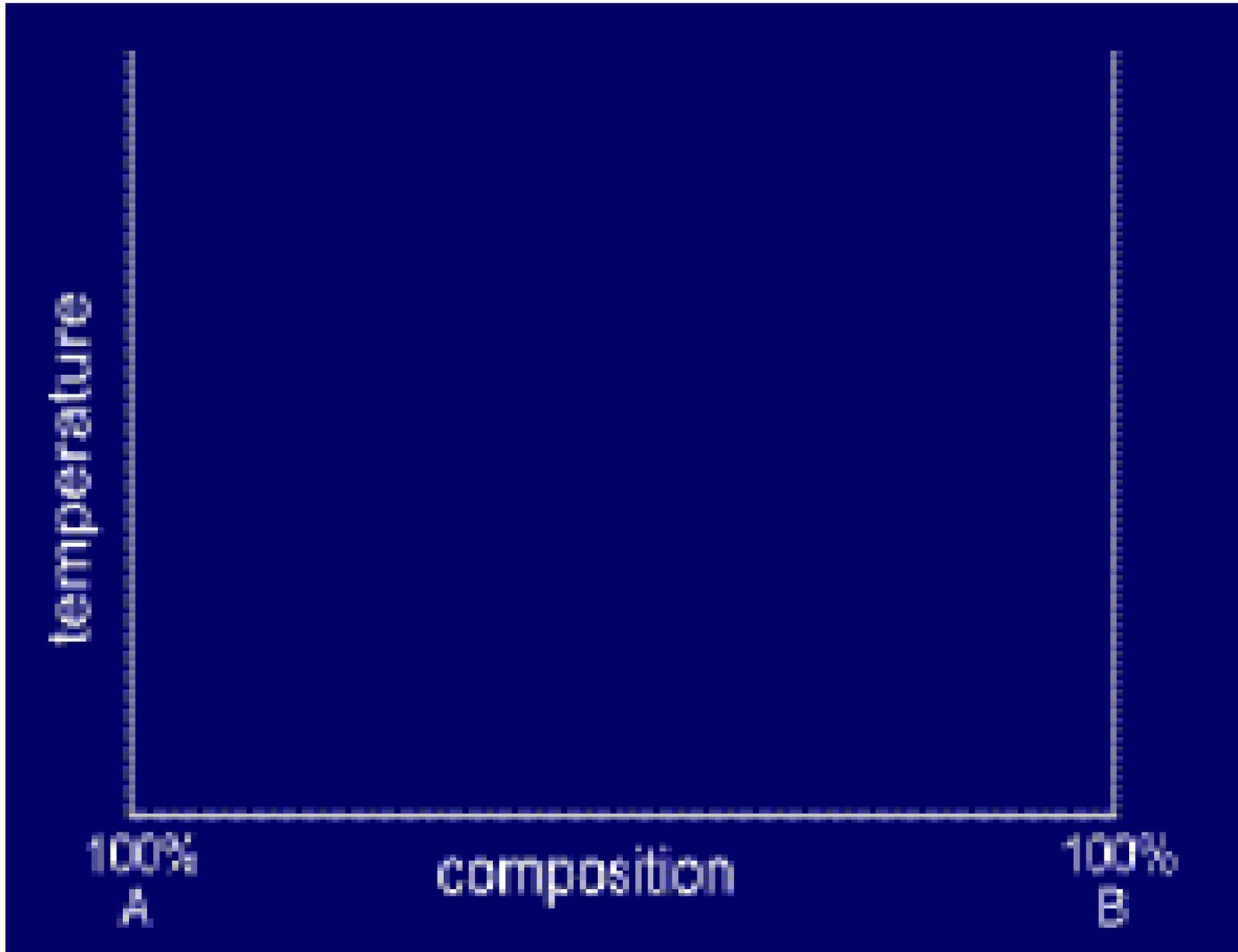
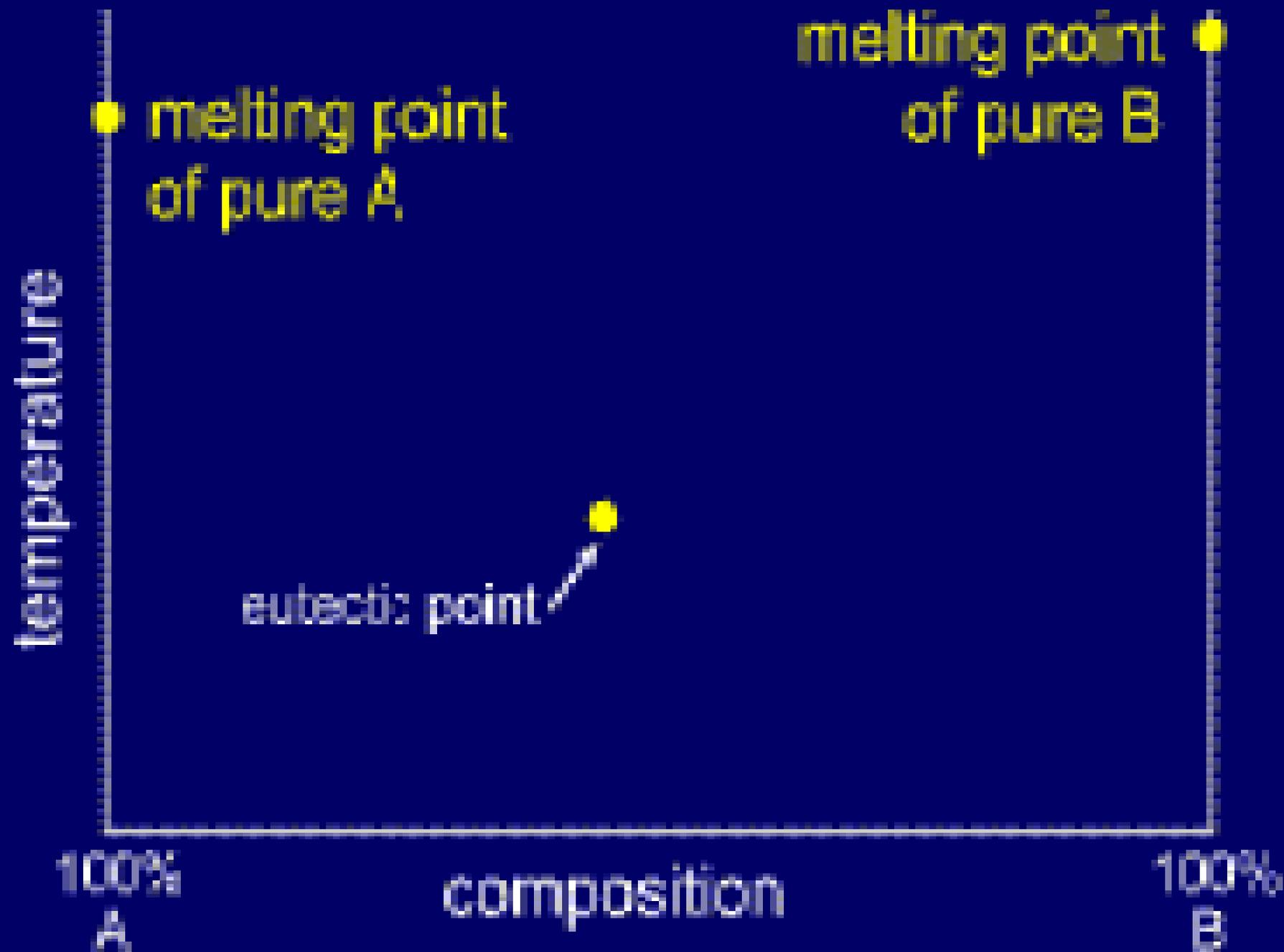
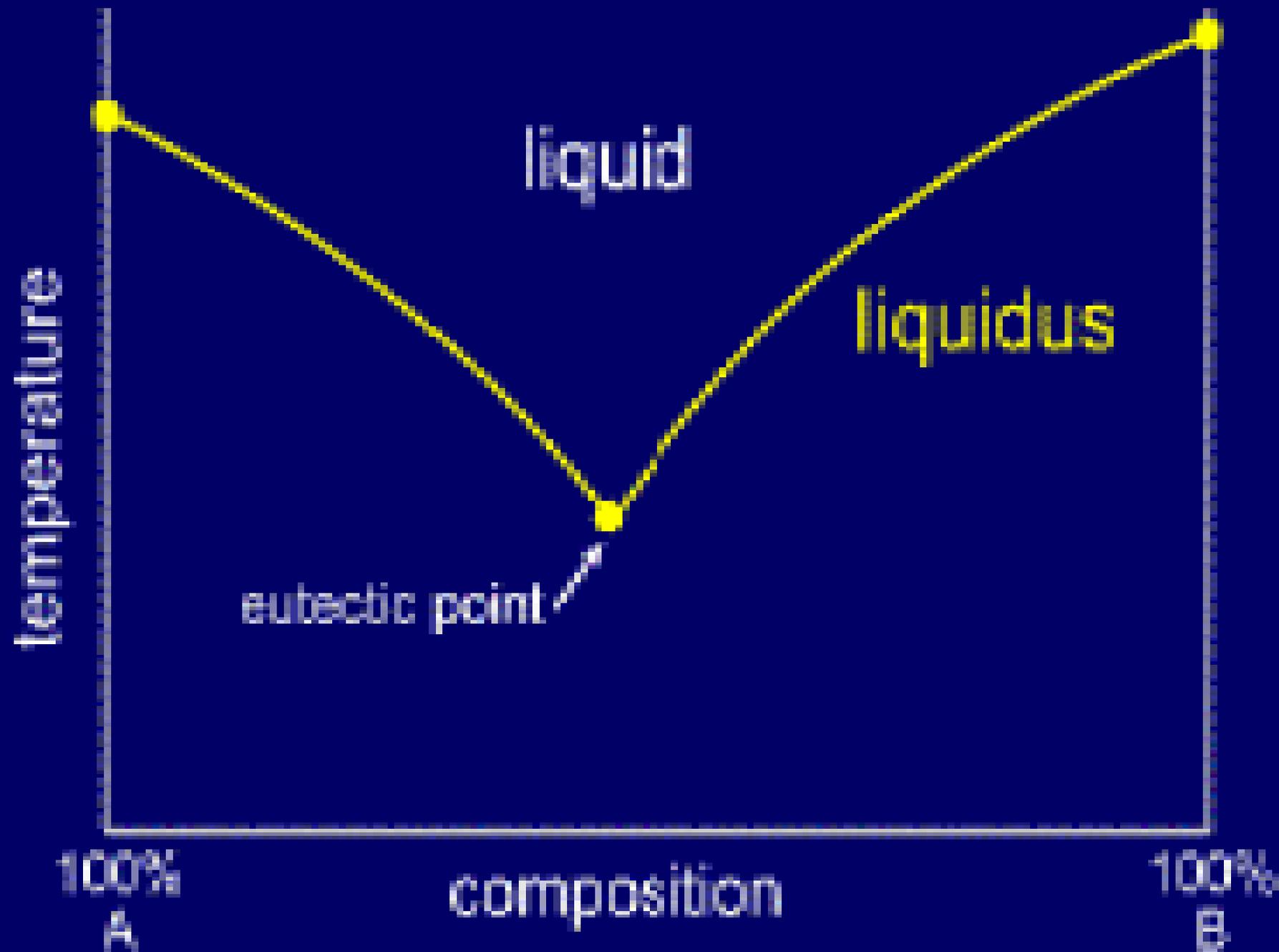


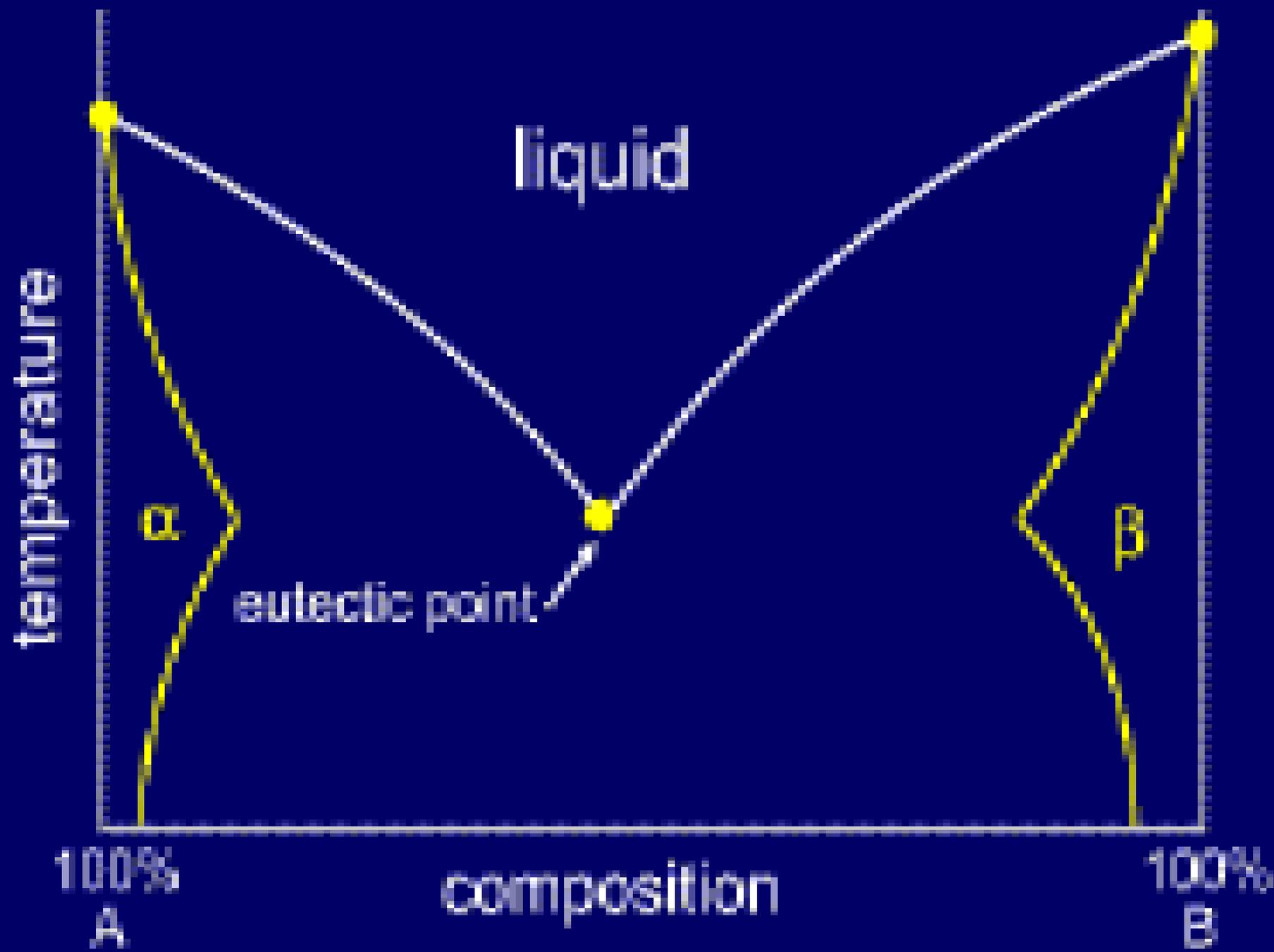
Diagrama de fases eutéctico plomo-estaño. Se presenta solución sólida limitada de $\alpha + \beta$

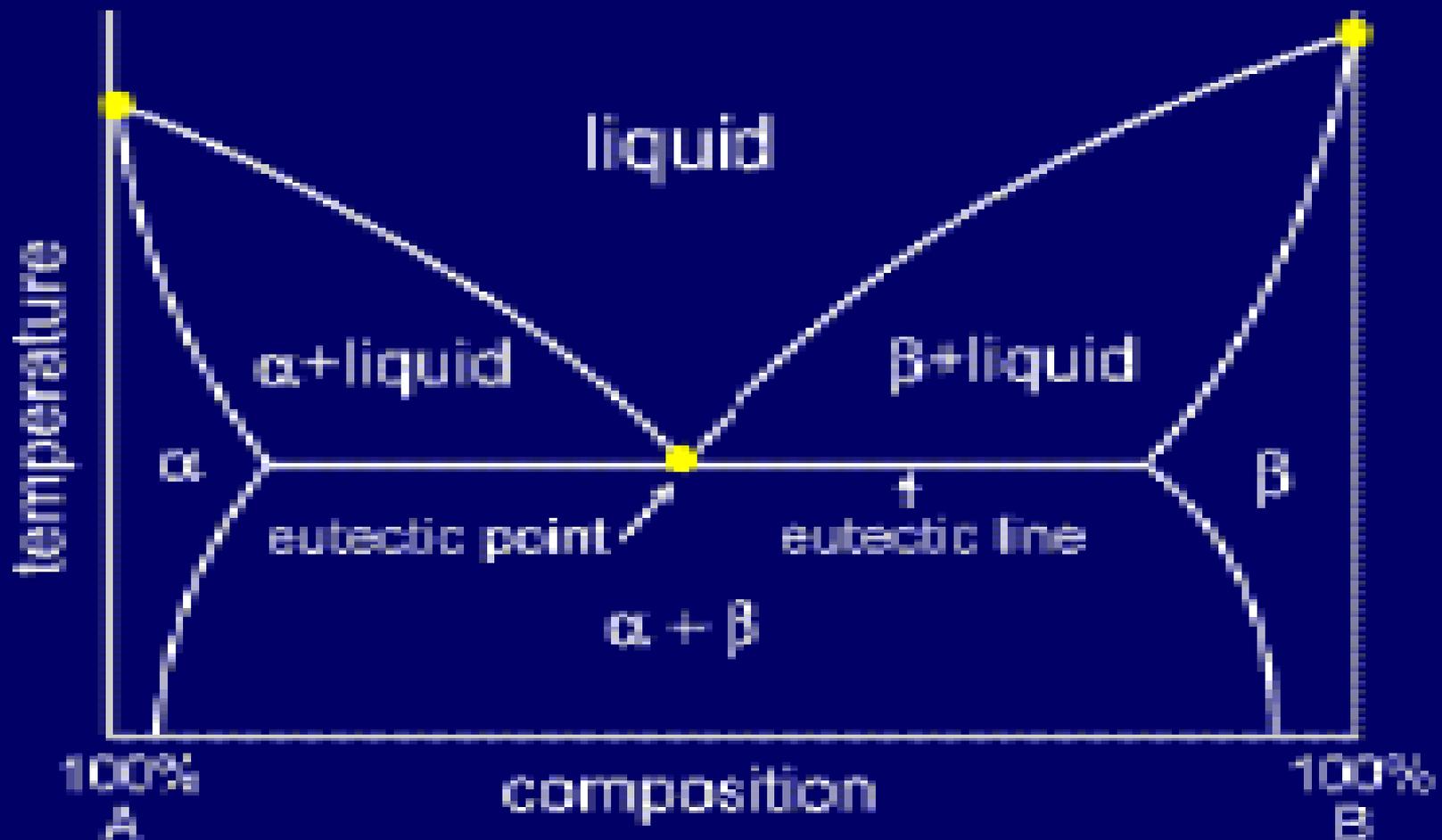
Diagrama de fases de dos soluciones solidas











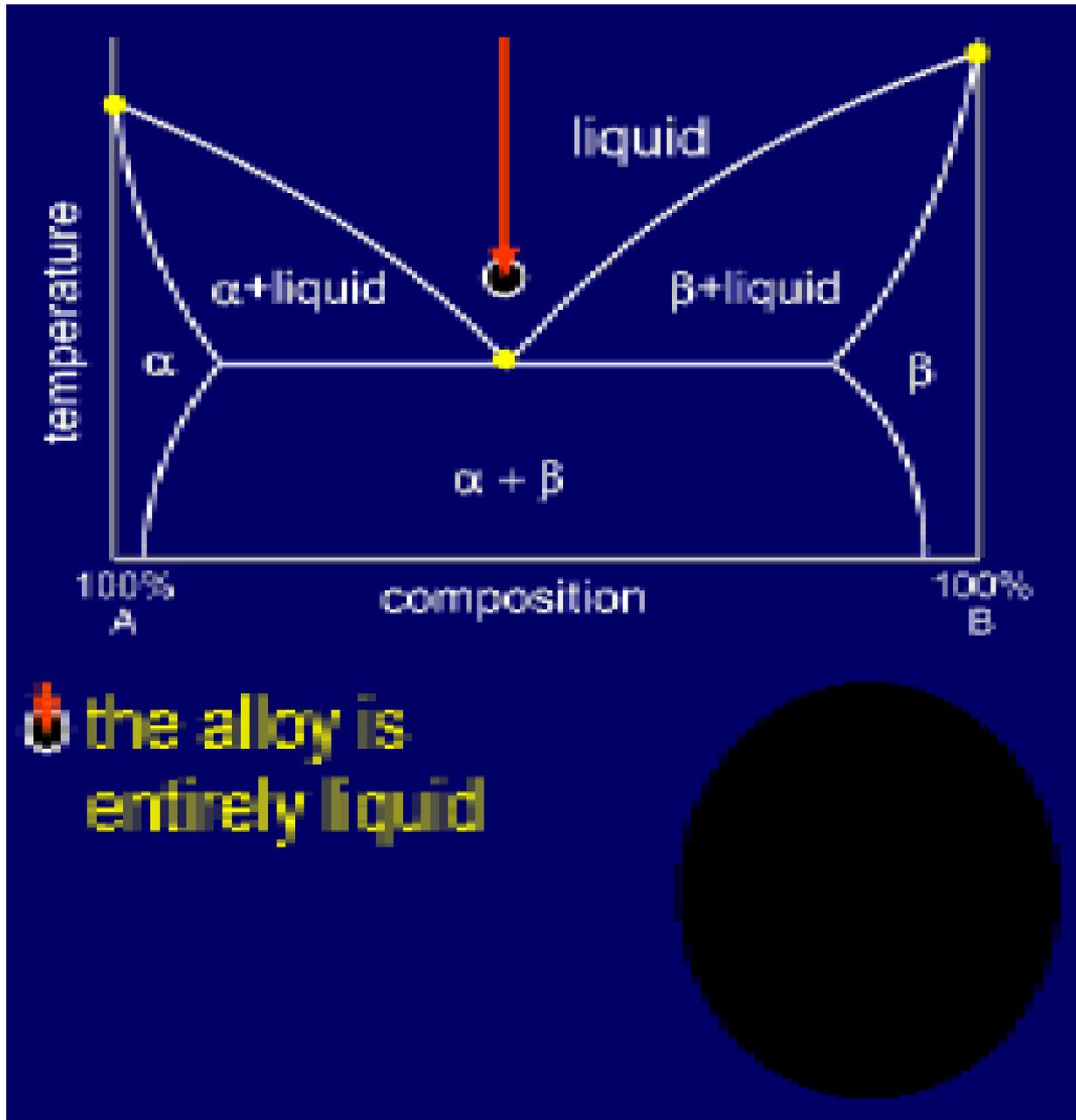
Soluciones sólidas α y β = fases terminales

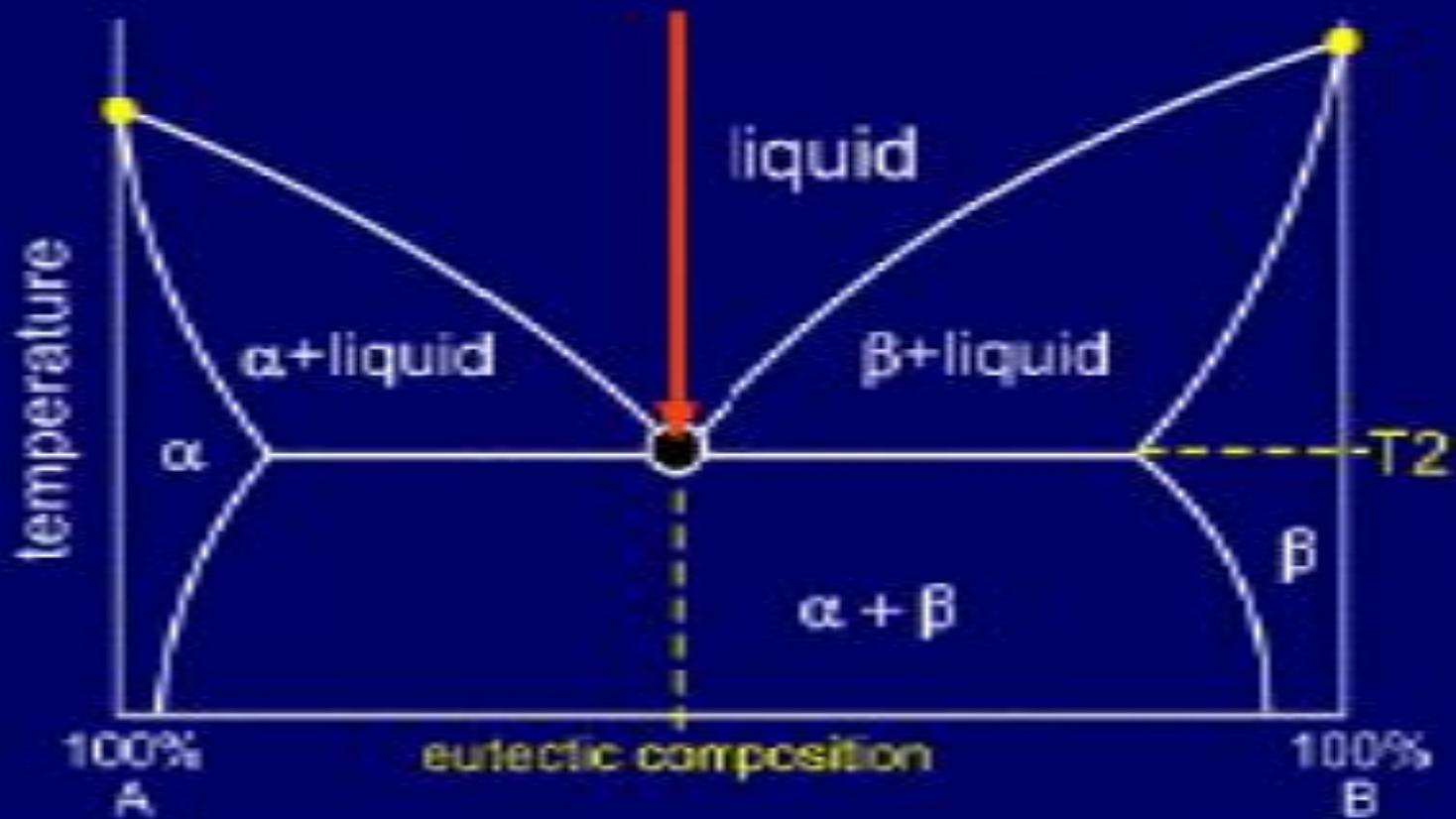
Línea eutéctica = temperatura eutéctica

α o β + líquido = región bifásica (sólido y líquido)

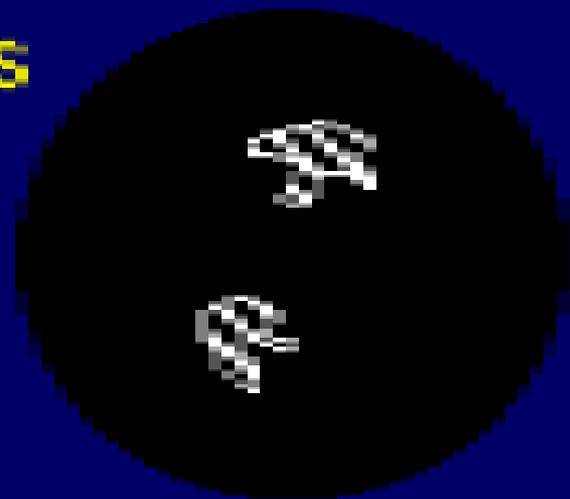
$\alpha + \beta$ = región bifásica (mezcla sólida)

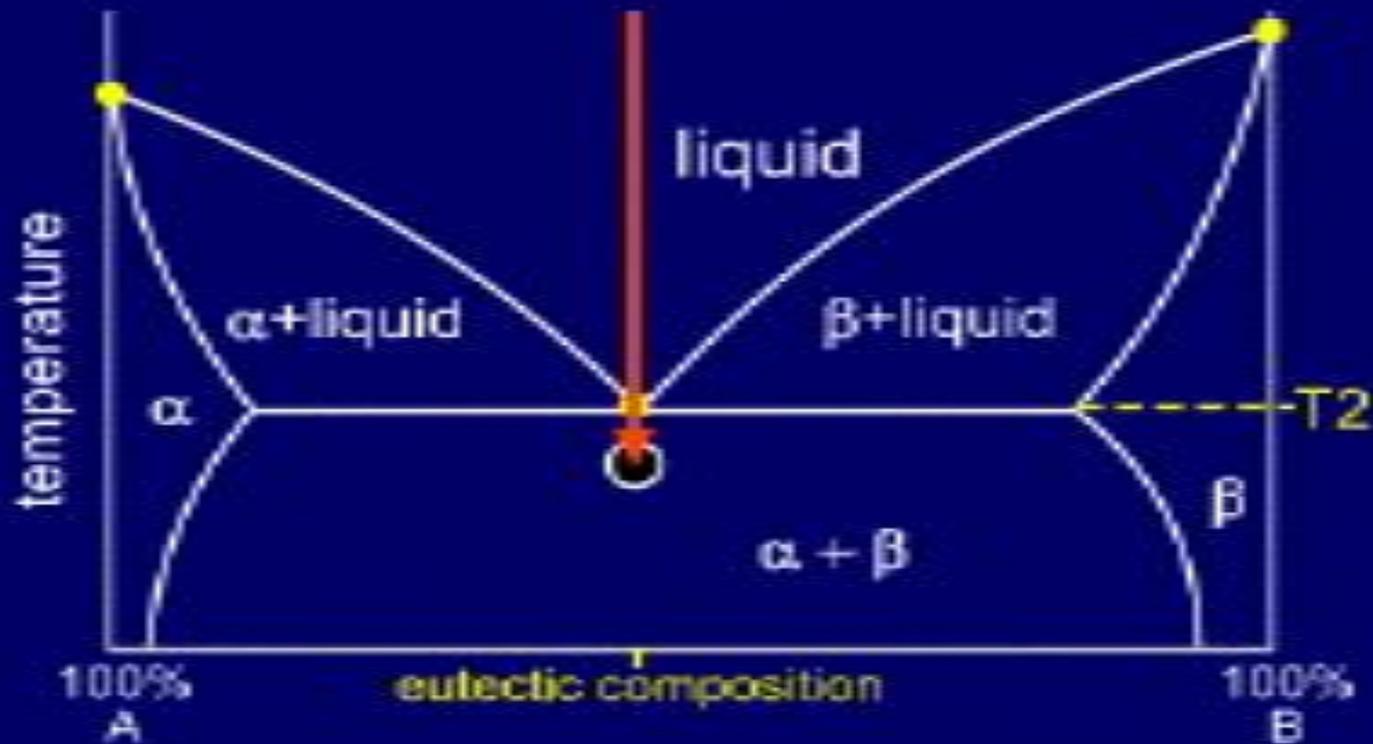
Microestructuras para una mezcla de composición eutéctica



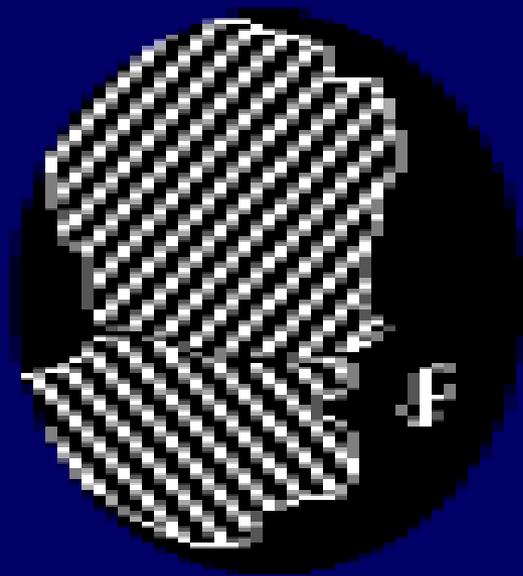


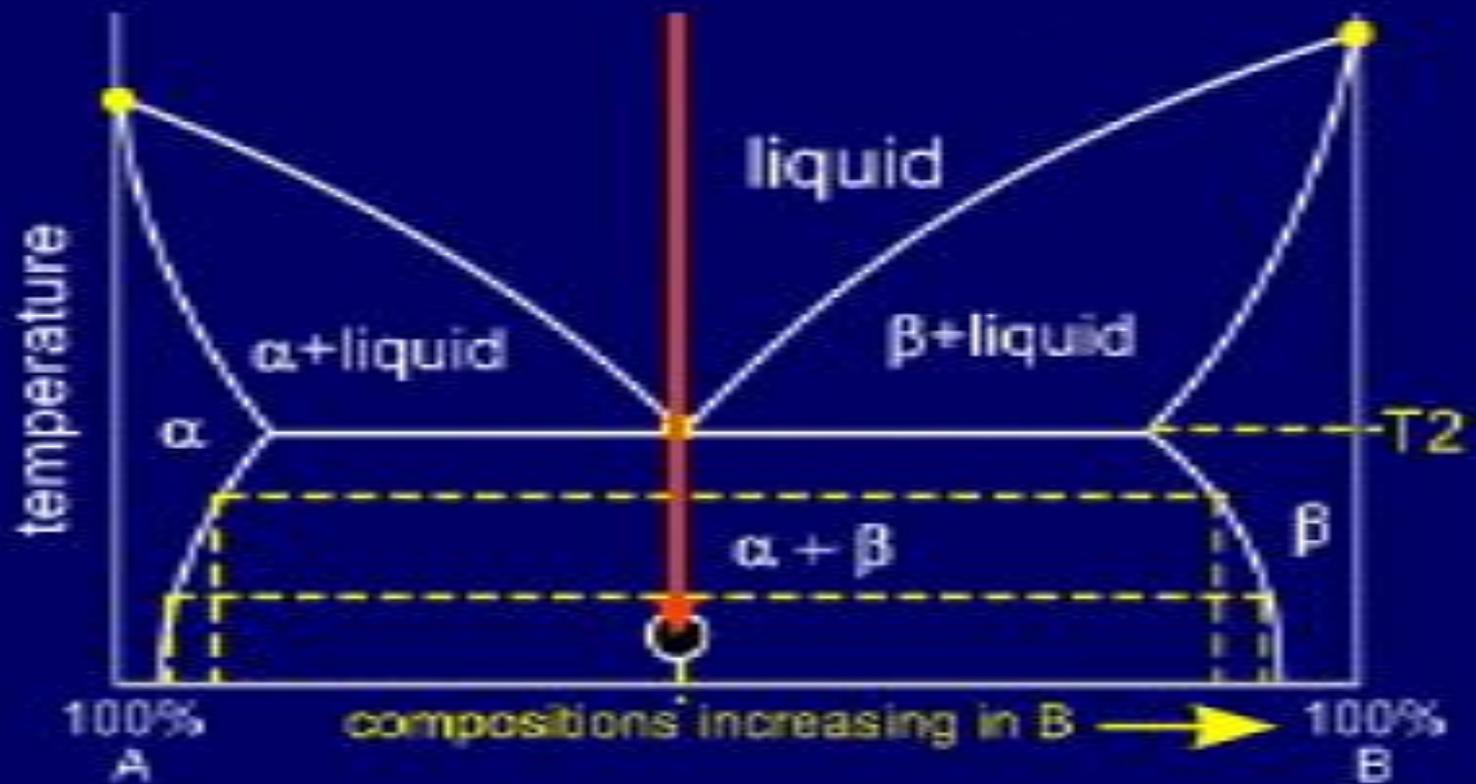
🔥 solidification begins at nucleation sites



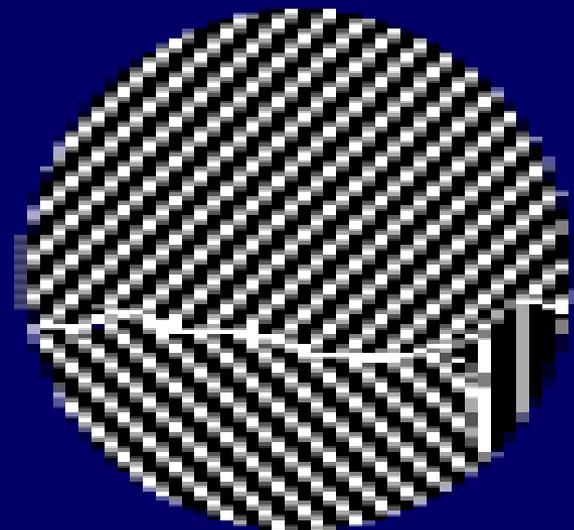


existing nucleation sites grow and further sites form

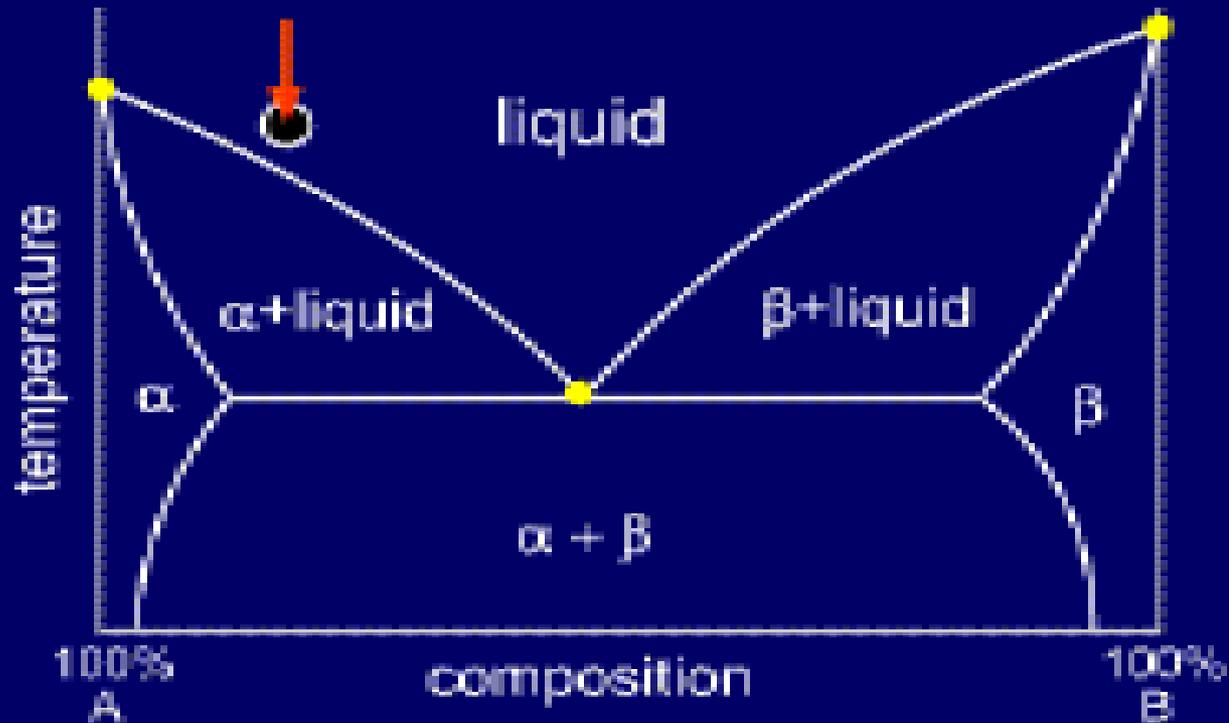




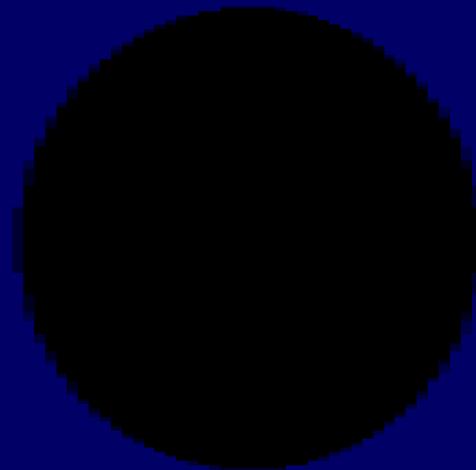
🔥 finally the entire alloy will solidify

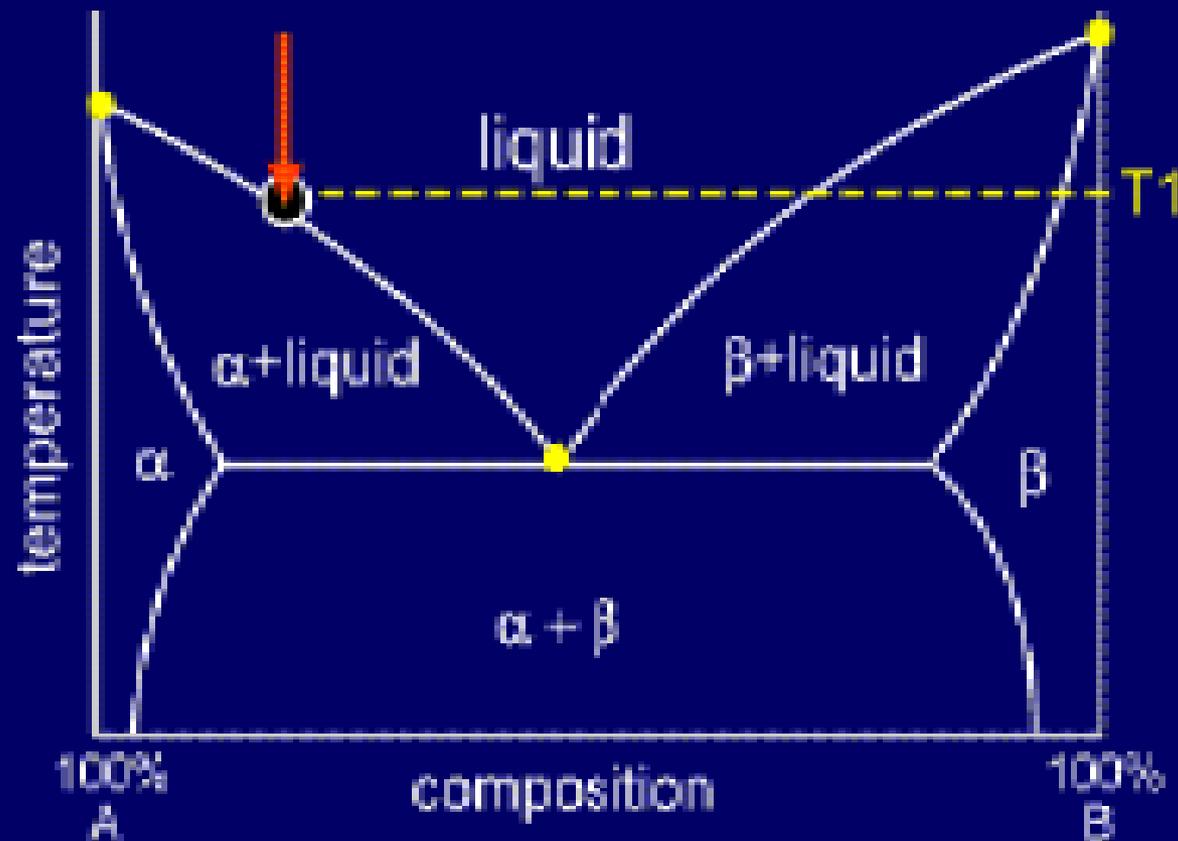


Aleación de composición hipoeutéctica temperatura



 the alloy is entirely liquid

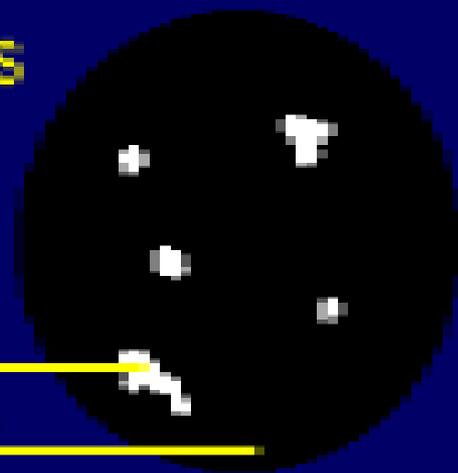


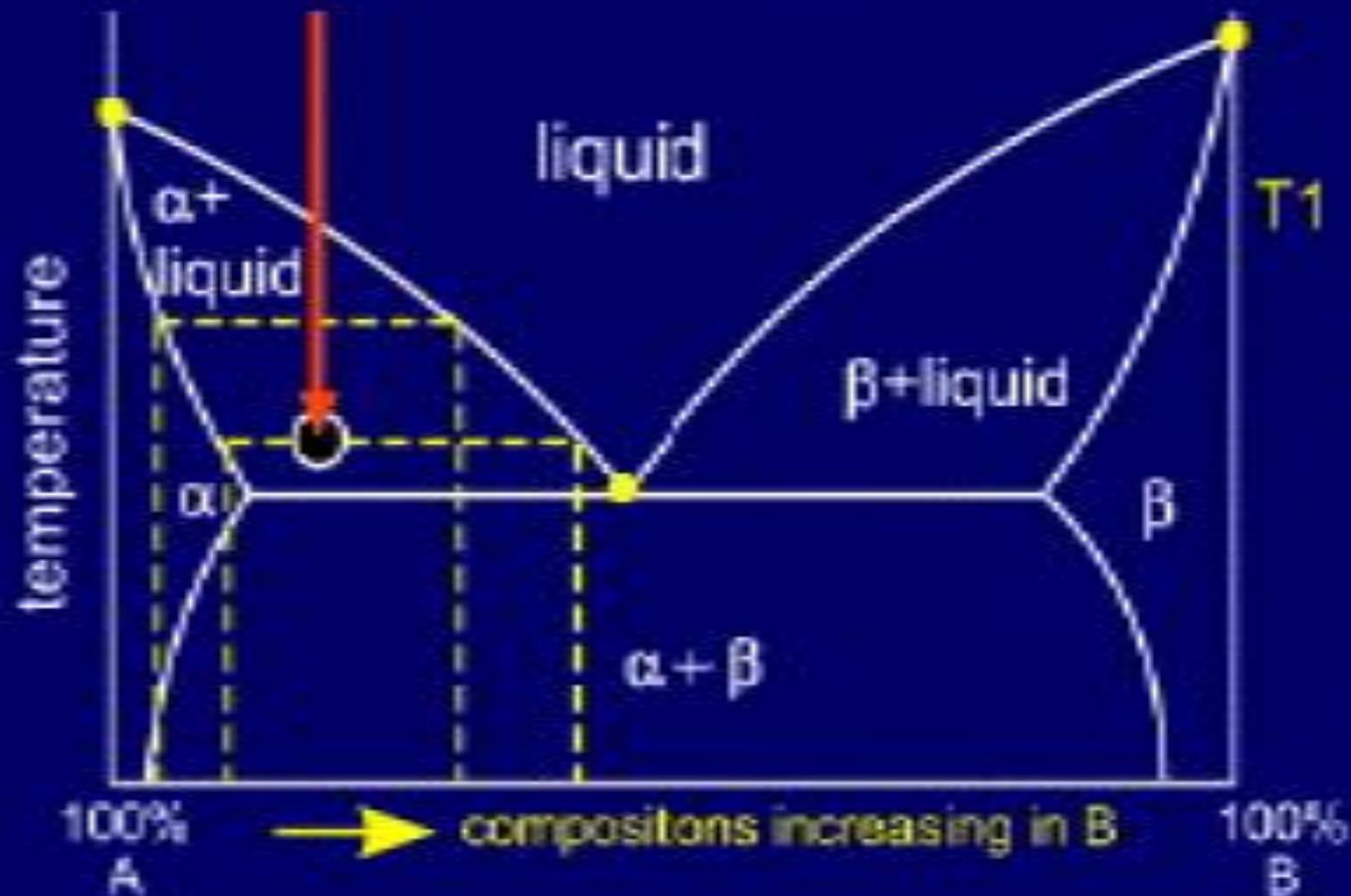


🔥 solidification begins at nucleation sites.

solid α

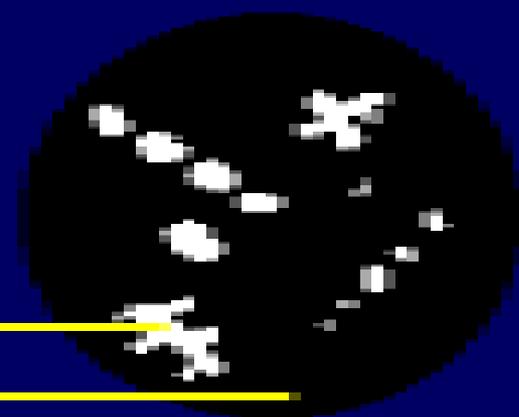
liquid

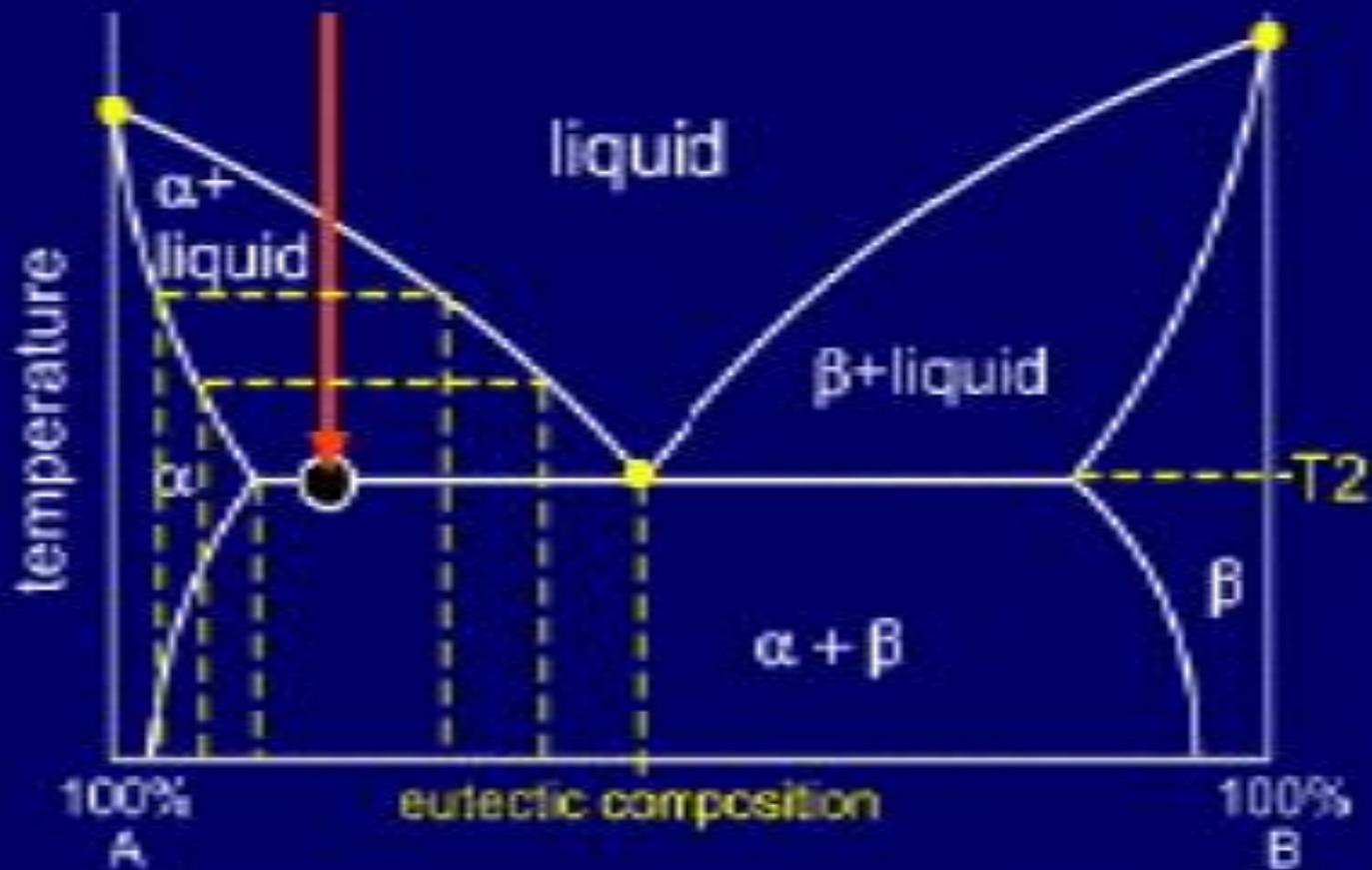




 existing nucleation sites grow and further sites form

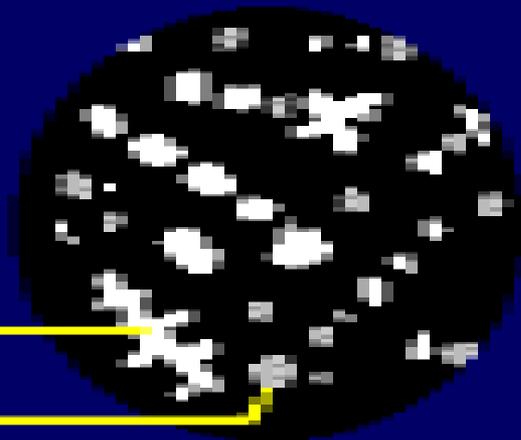
solid α —————
 liquid —————

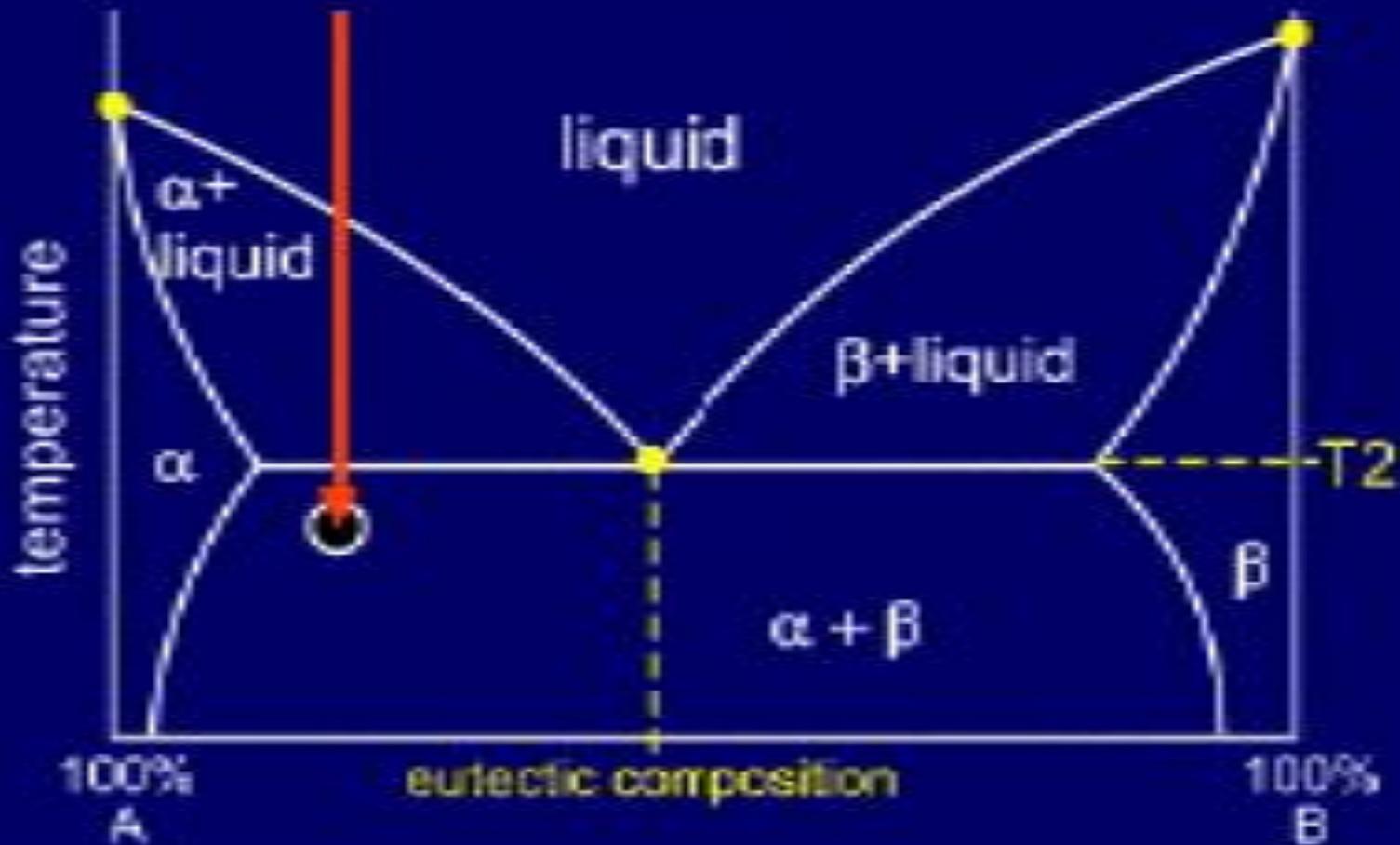





 nucleation of
 eutectic
 composition

solid α 
 solid eutectic 

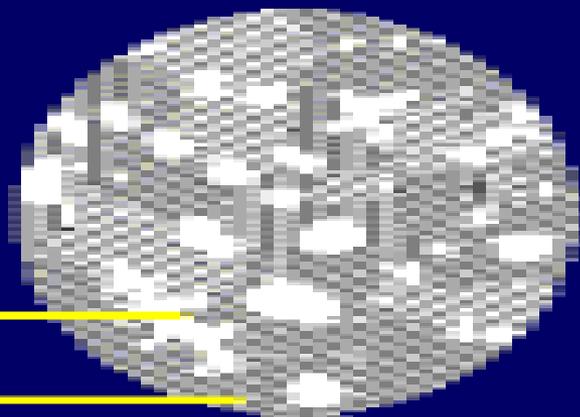


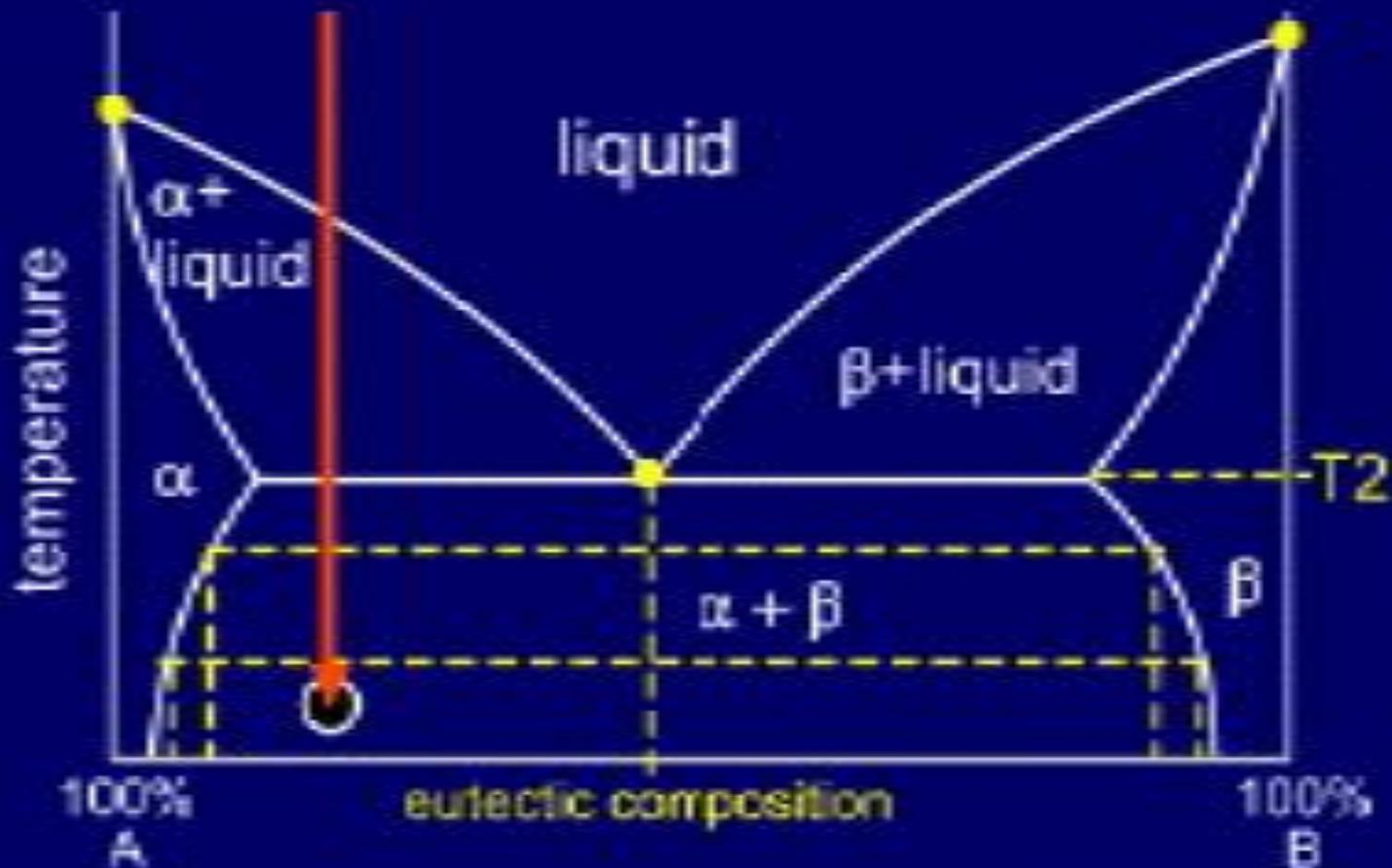


 eutectic: grains continue to grow and nucleate:

solid α

solid eutectic

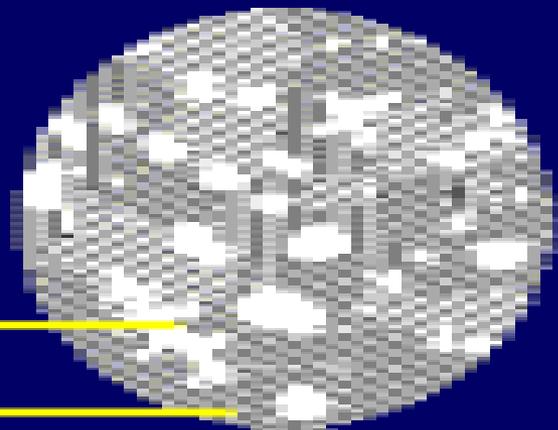




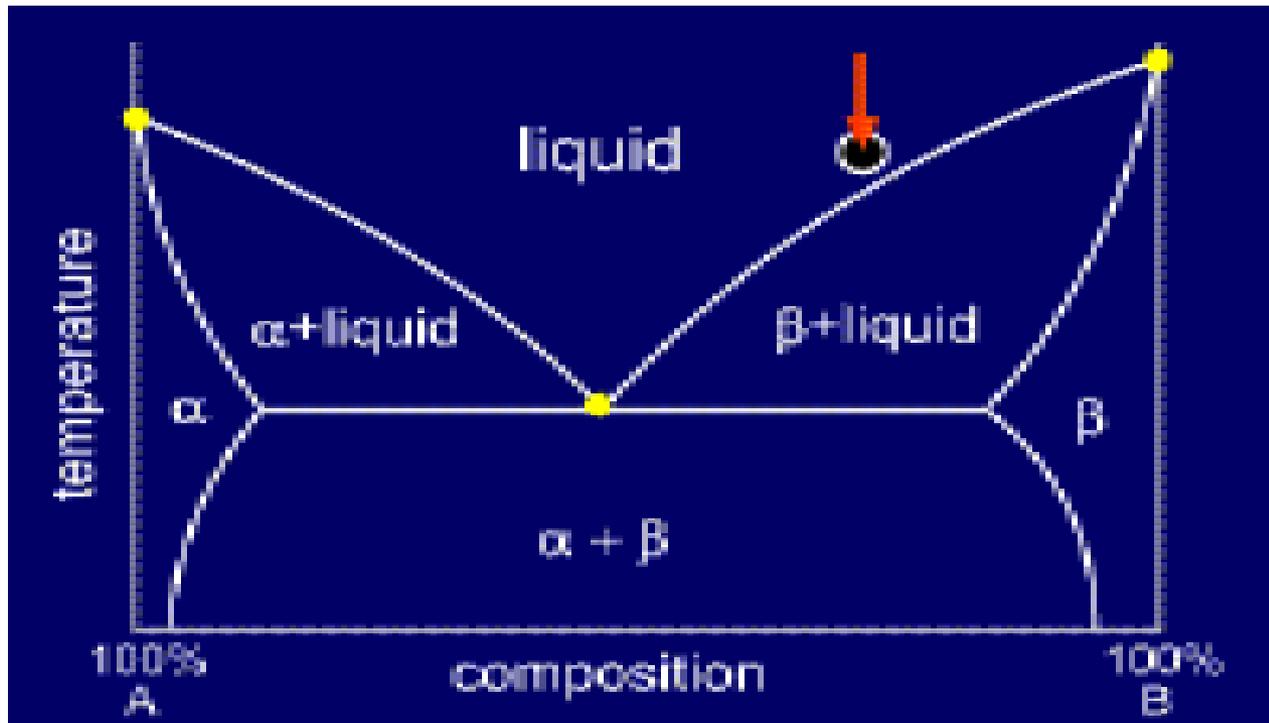
🔴 finally the entire alloy will solidify

solid α

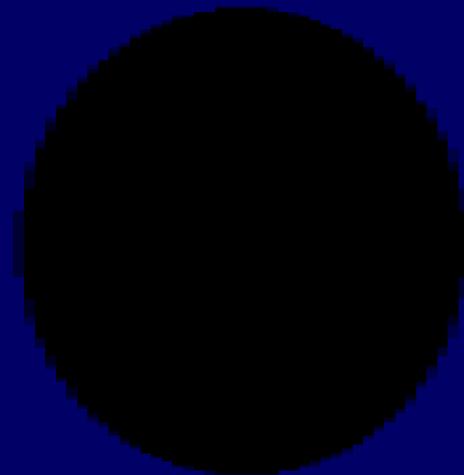
solid eutectic

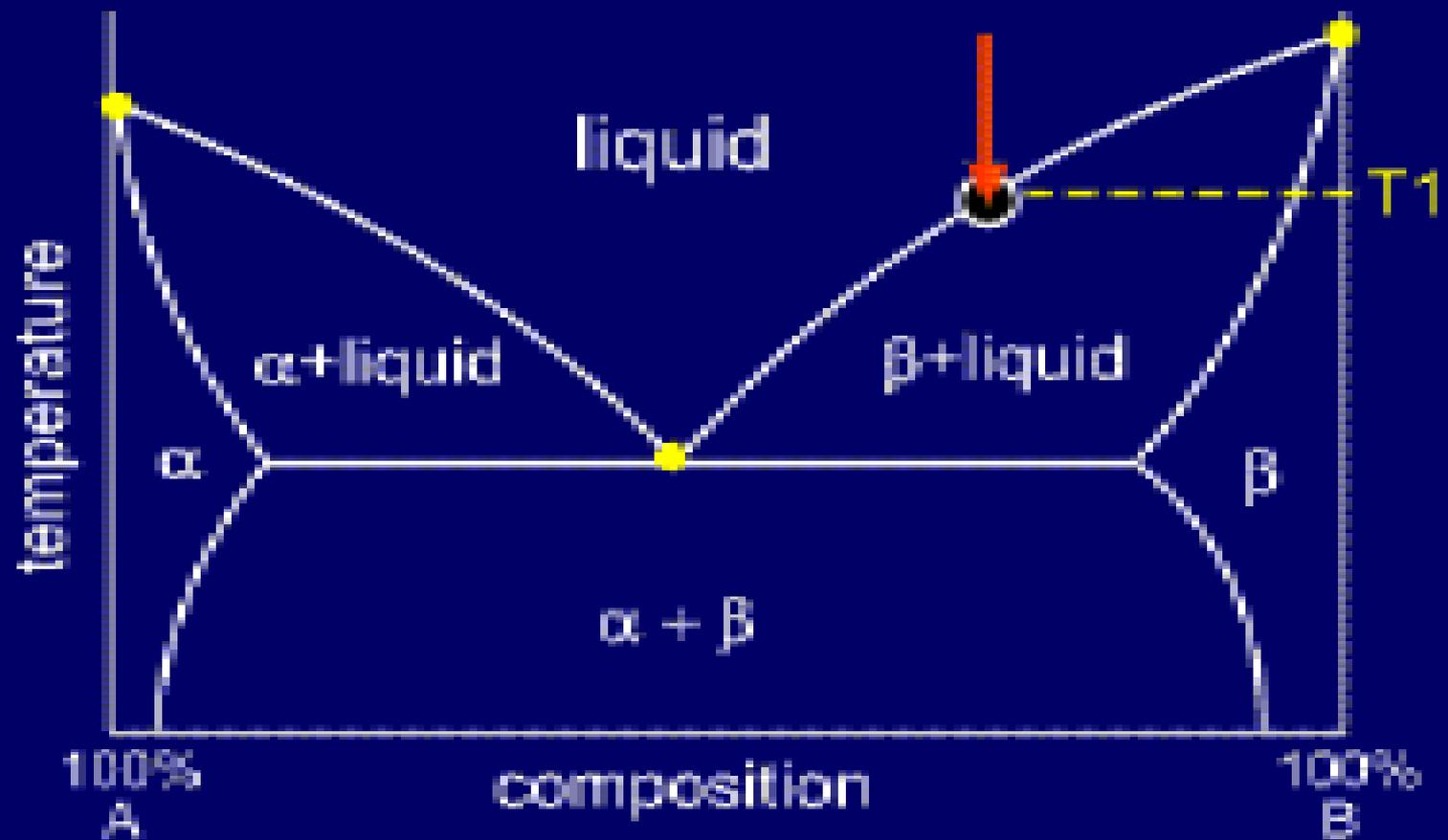


Aleación de composición hipereutética temperatura



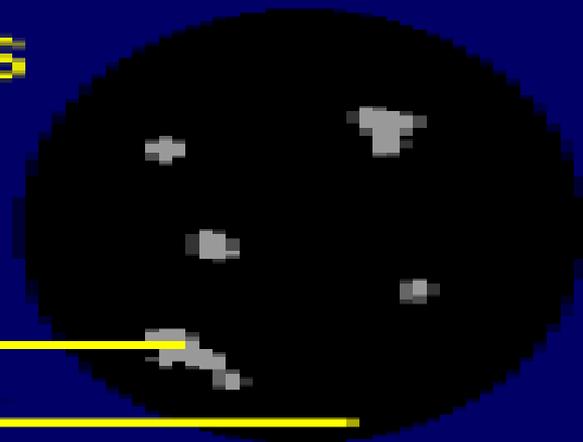
the alloy is
entirely liquid

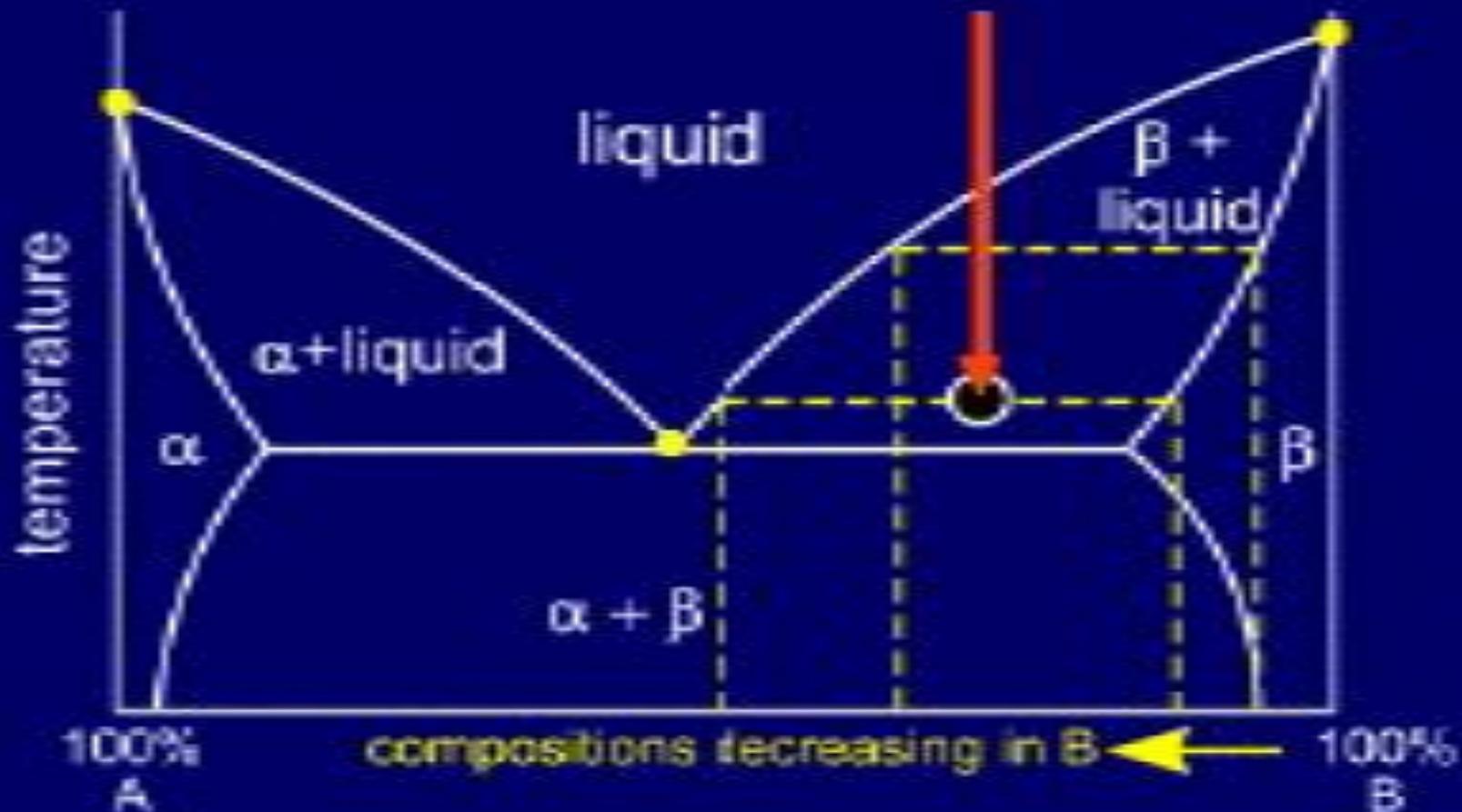




 solidification begins at nucleation sites

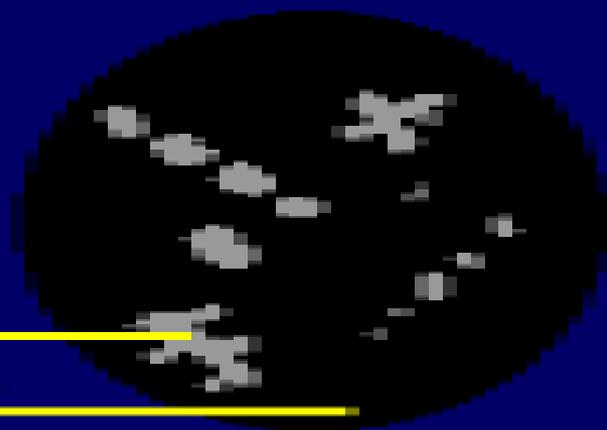
solid β
liquid

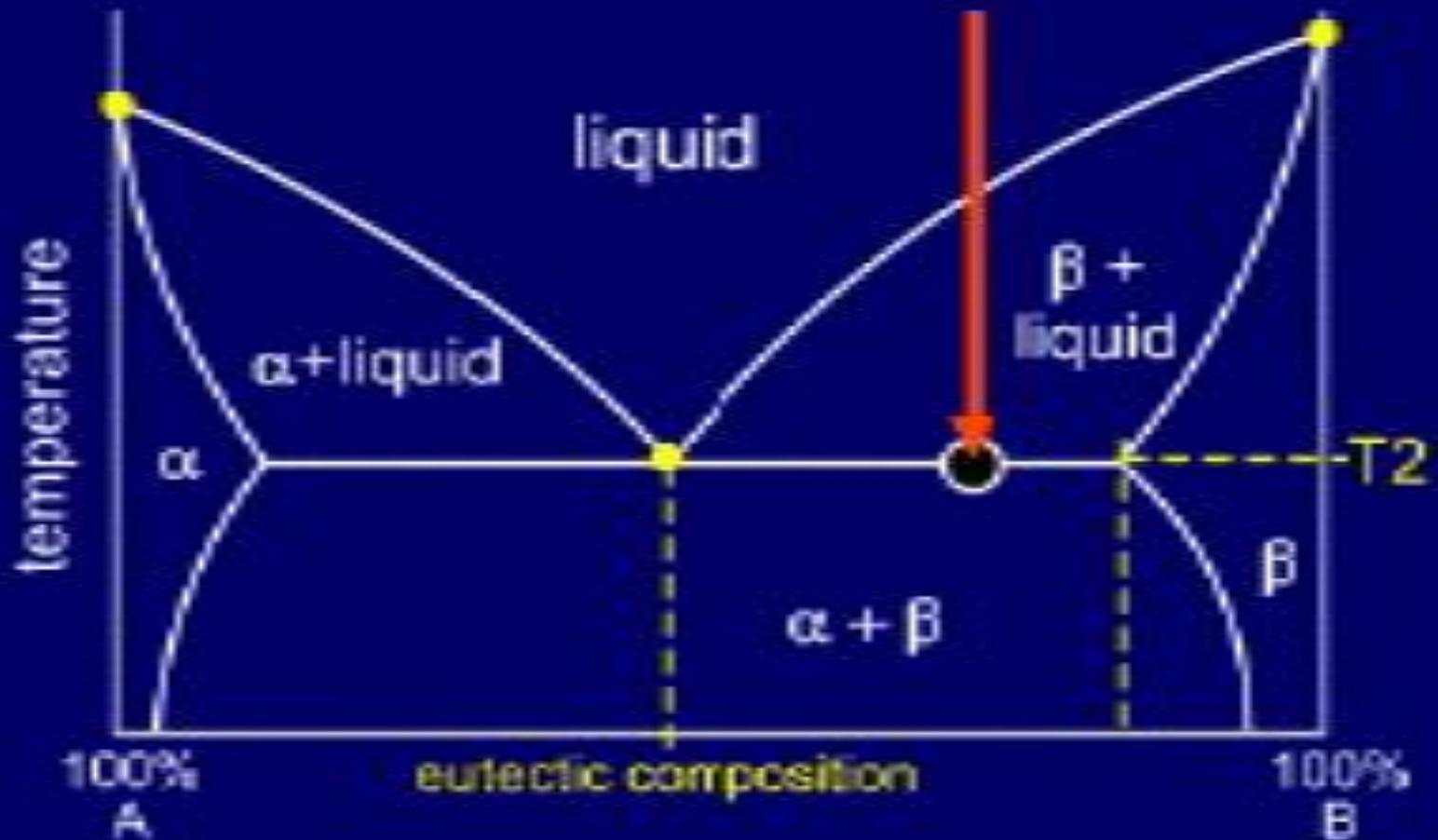




existing nucleation sites grow and further sites form

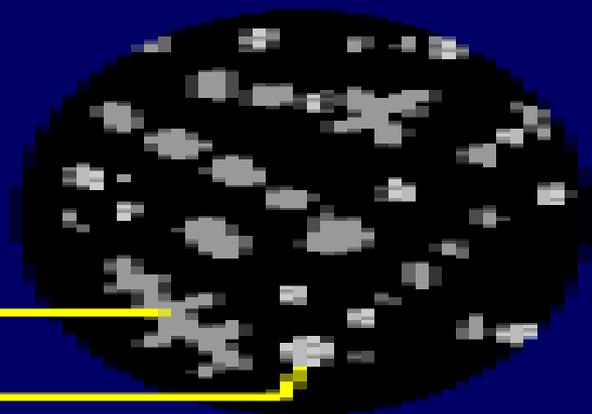
solid β
liquid

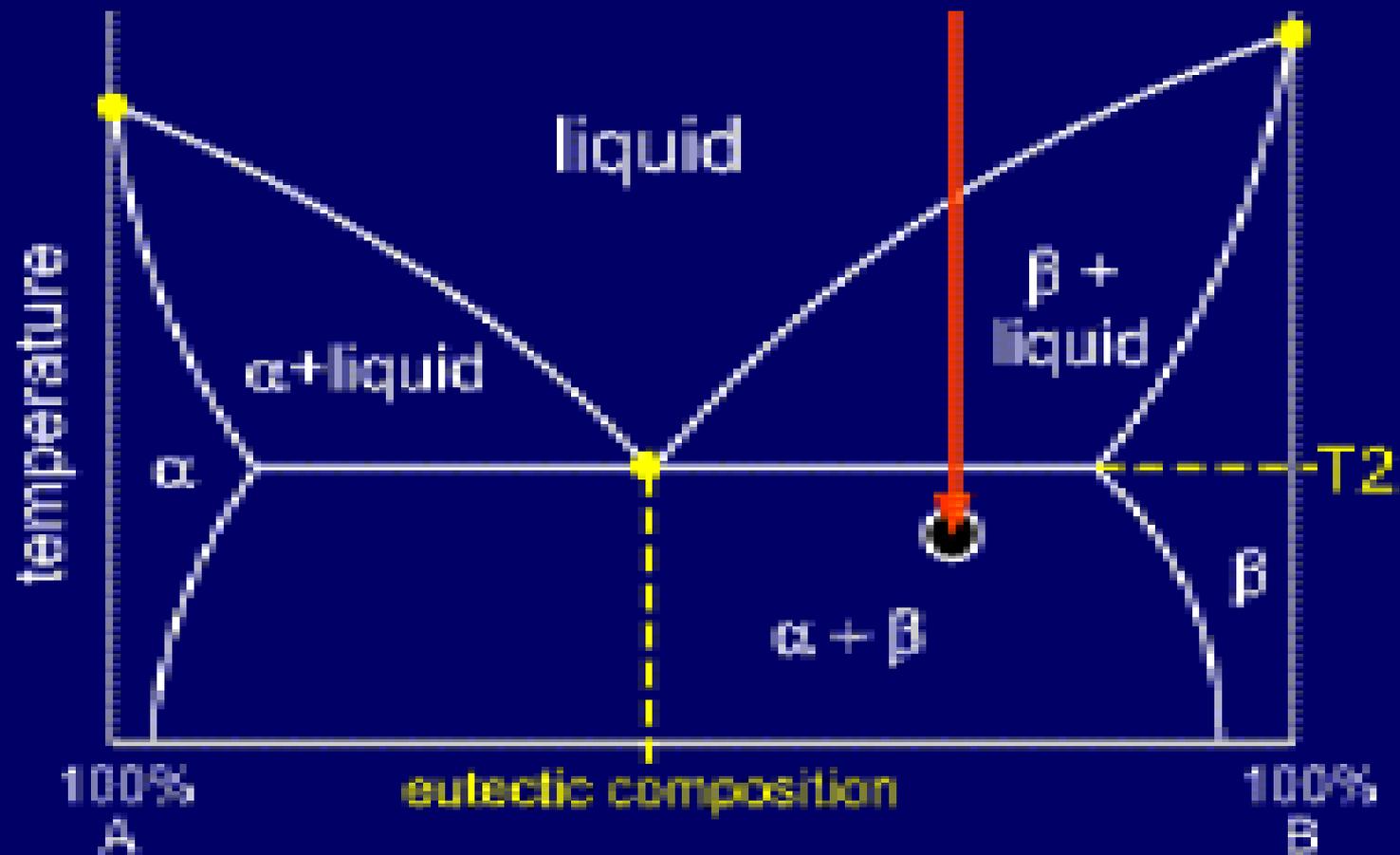




 nucleation of
 eutectic
 composition

solid β
 solid eutectic

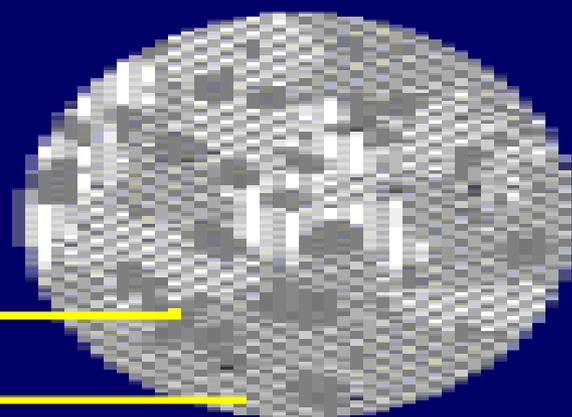


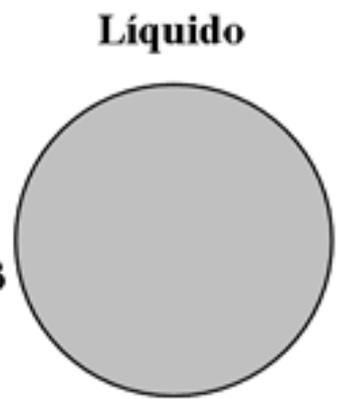
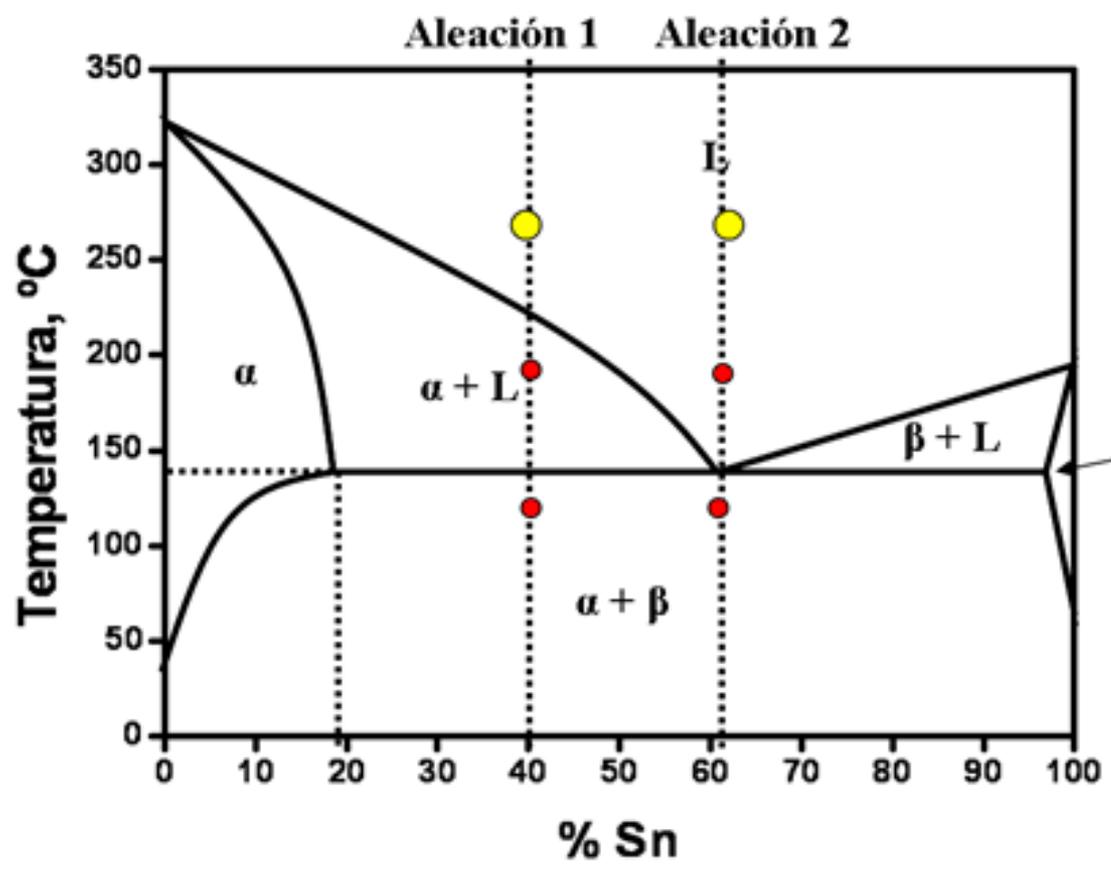
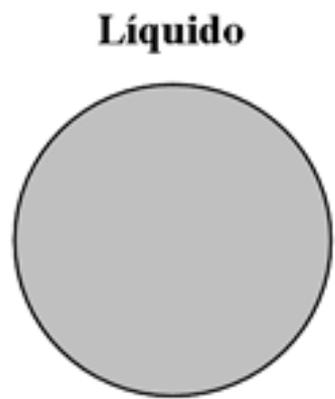


 eutectic grains continue to grow and nucleate

solid β 

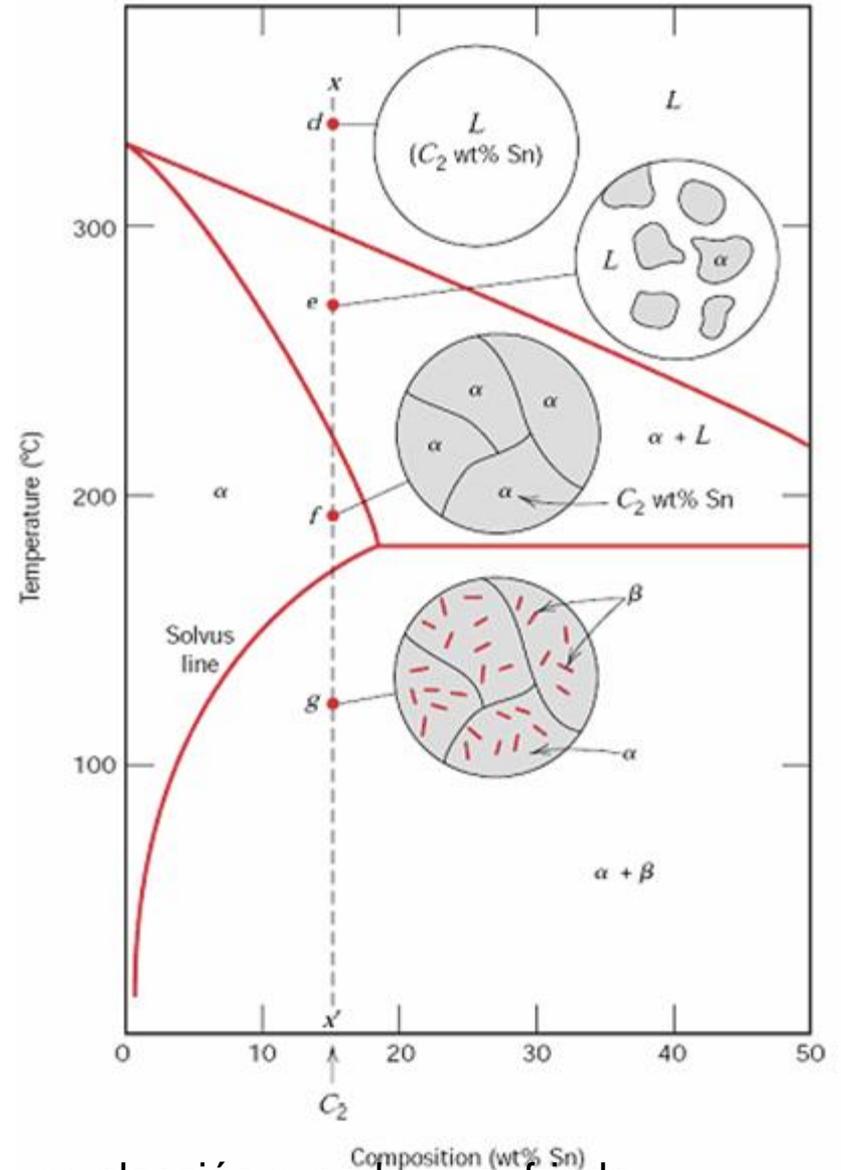
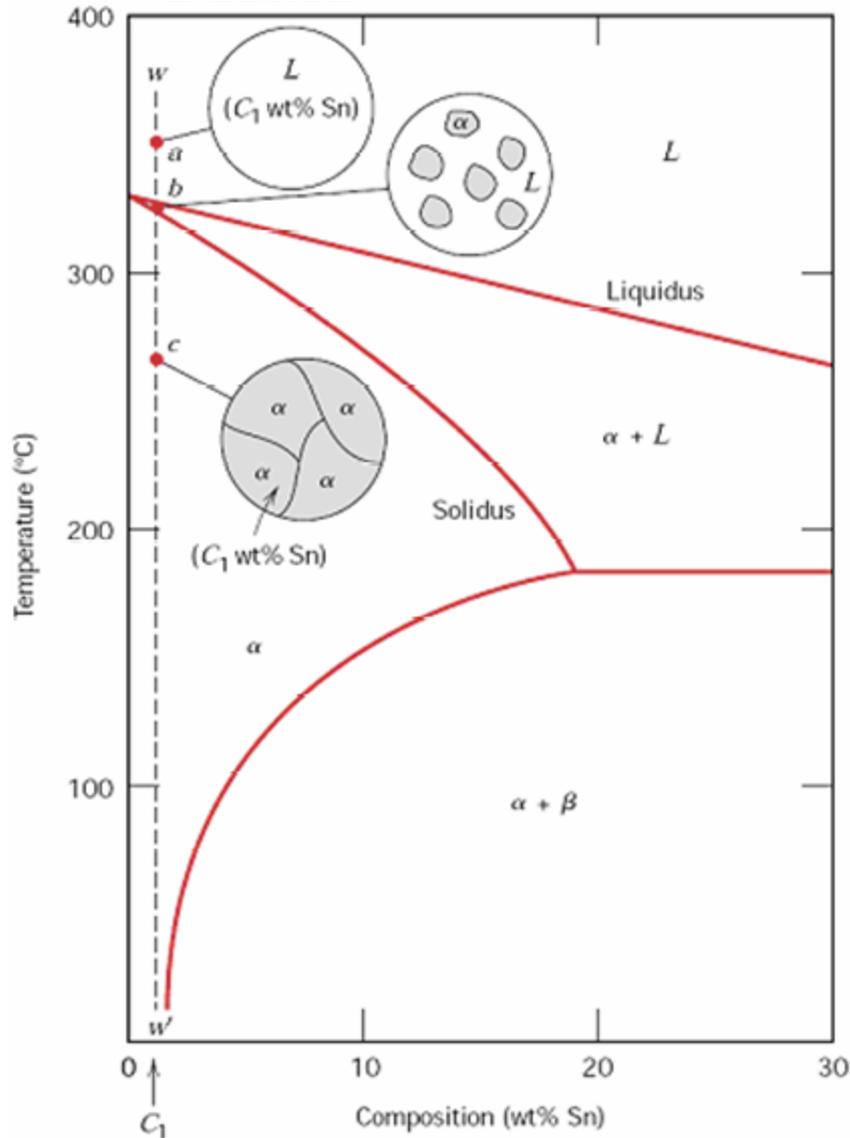
solid eutectic 



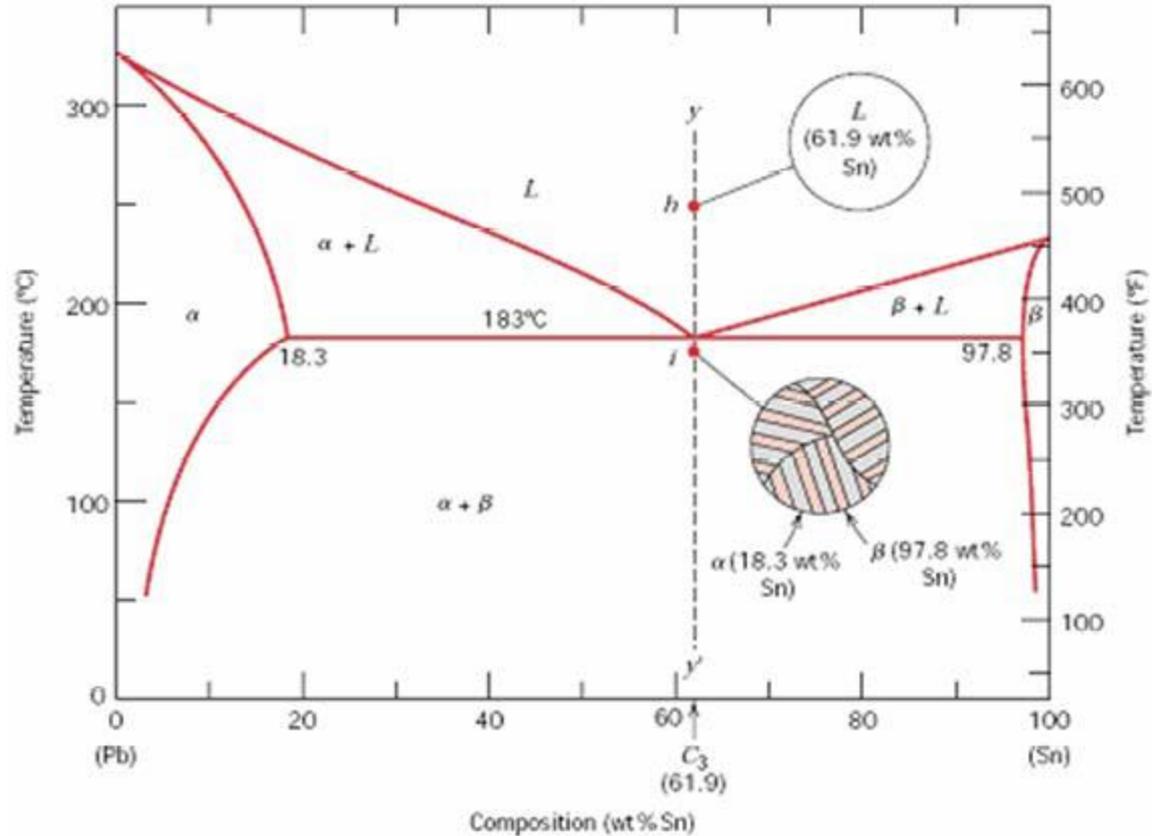


Solidificación y formación de compuestos en diagramas de fases

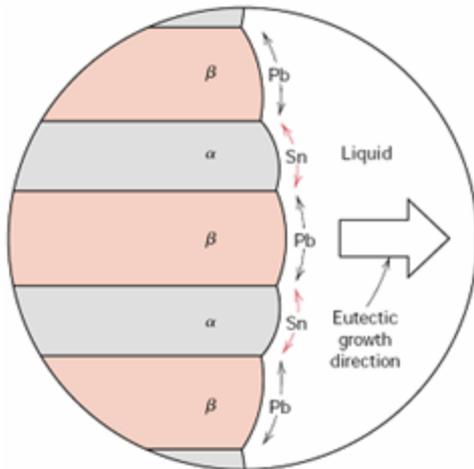
binarios



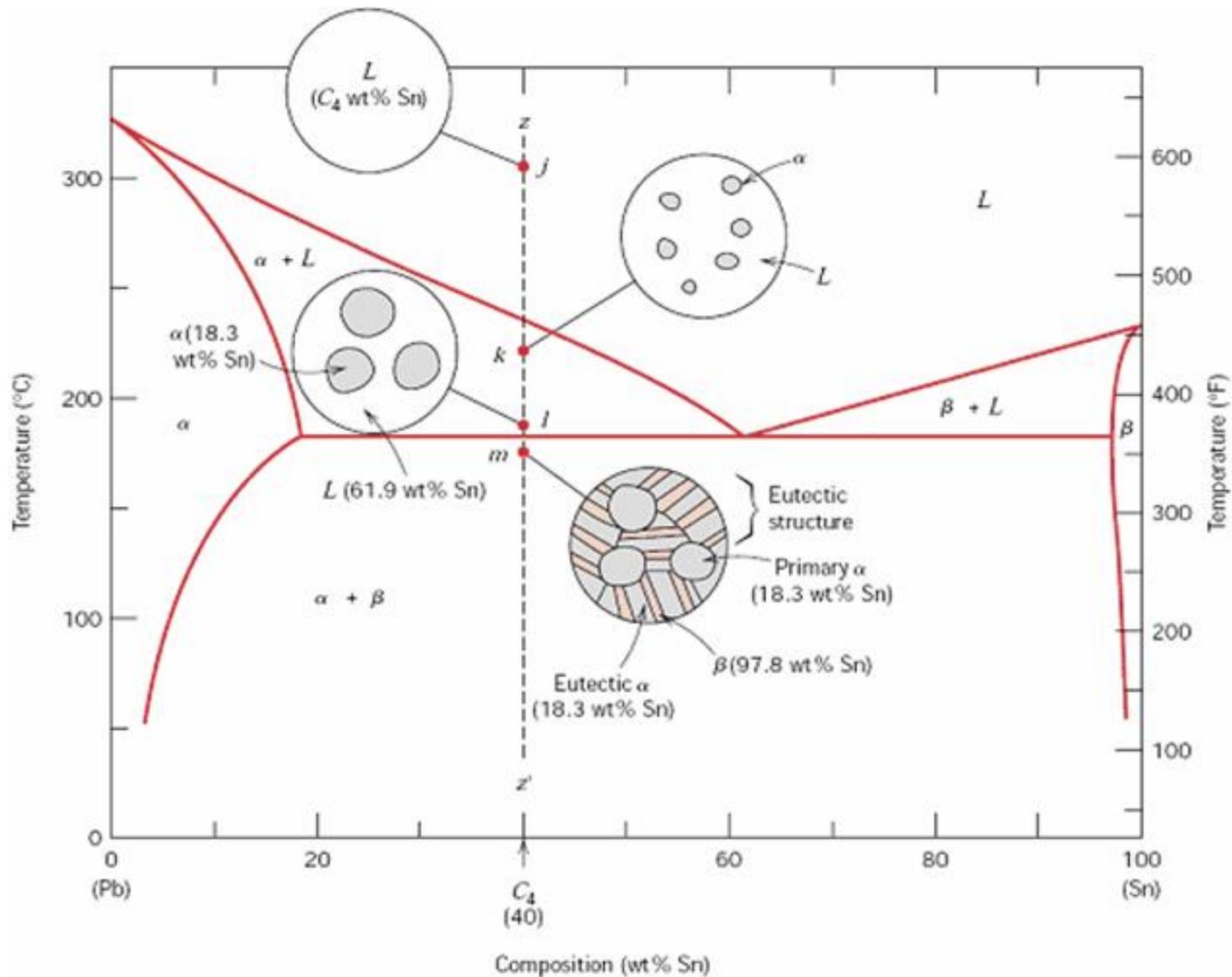
Microestructuras en el equilibrio para una aleación cuando es enfriada desde la región de fase líquida izq. a una composición C_1 ; Der. a una composición C_2



Microestructuras en el equilibrio para una aleación Pb-Sn de composición eutéctica C3 sobre (proeutéctico) y debajo de la temperatura eutéctica

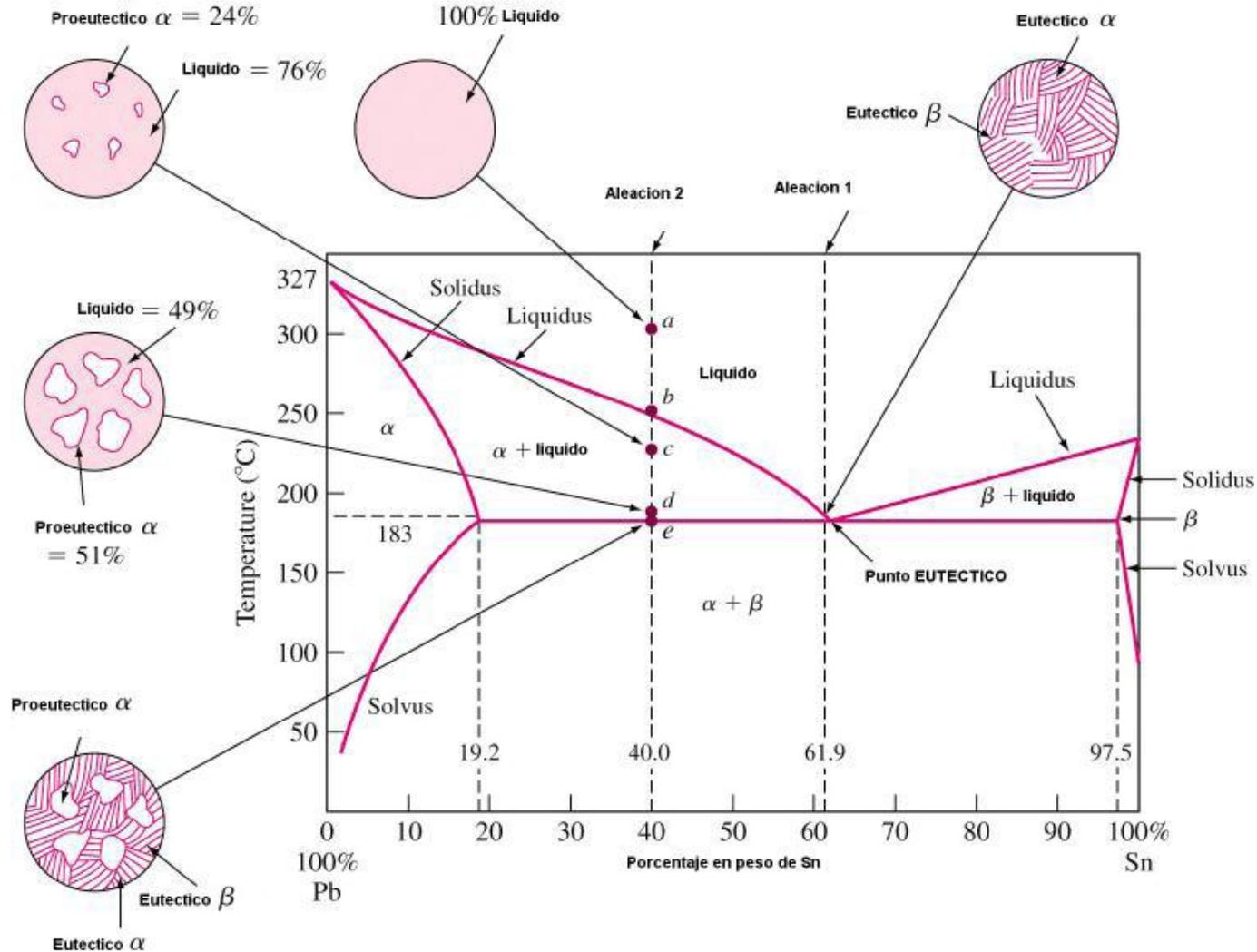


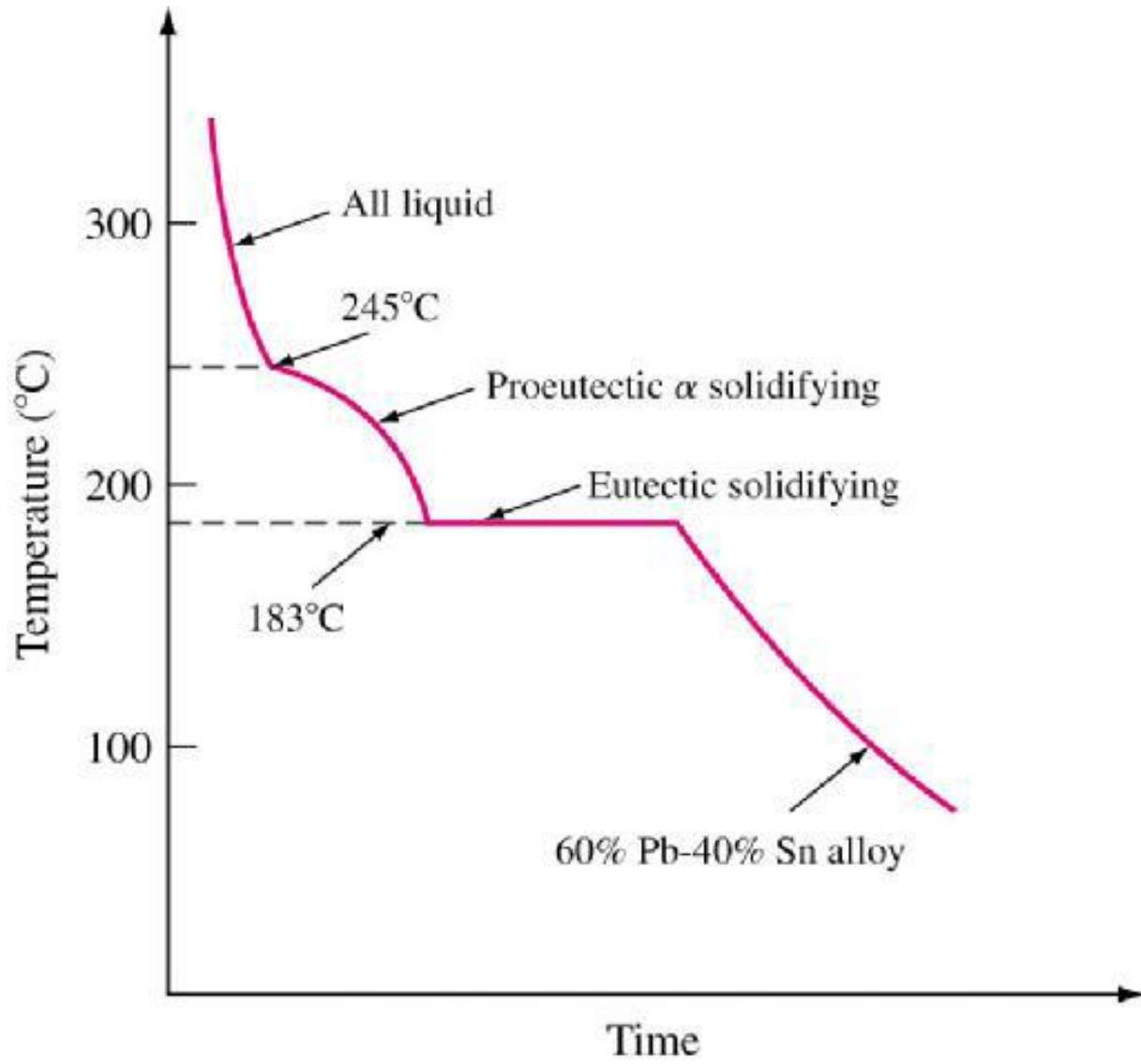
Fotomicrografía que muestra la estructura de la aleación Pb-Sn de composición eutéctica. Esta microestructura consiste en capas alternas de una fase α de solución sólida rica en Pb (Capas Oscuras) y una fase β de solución sólida rica en Sn



Microestructuras en el equilibrio para una aleación cuando es enfriada desde la región de fase líquida a una composición C_4

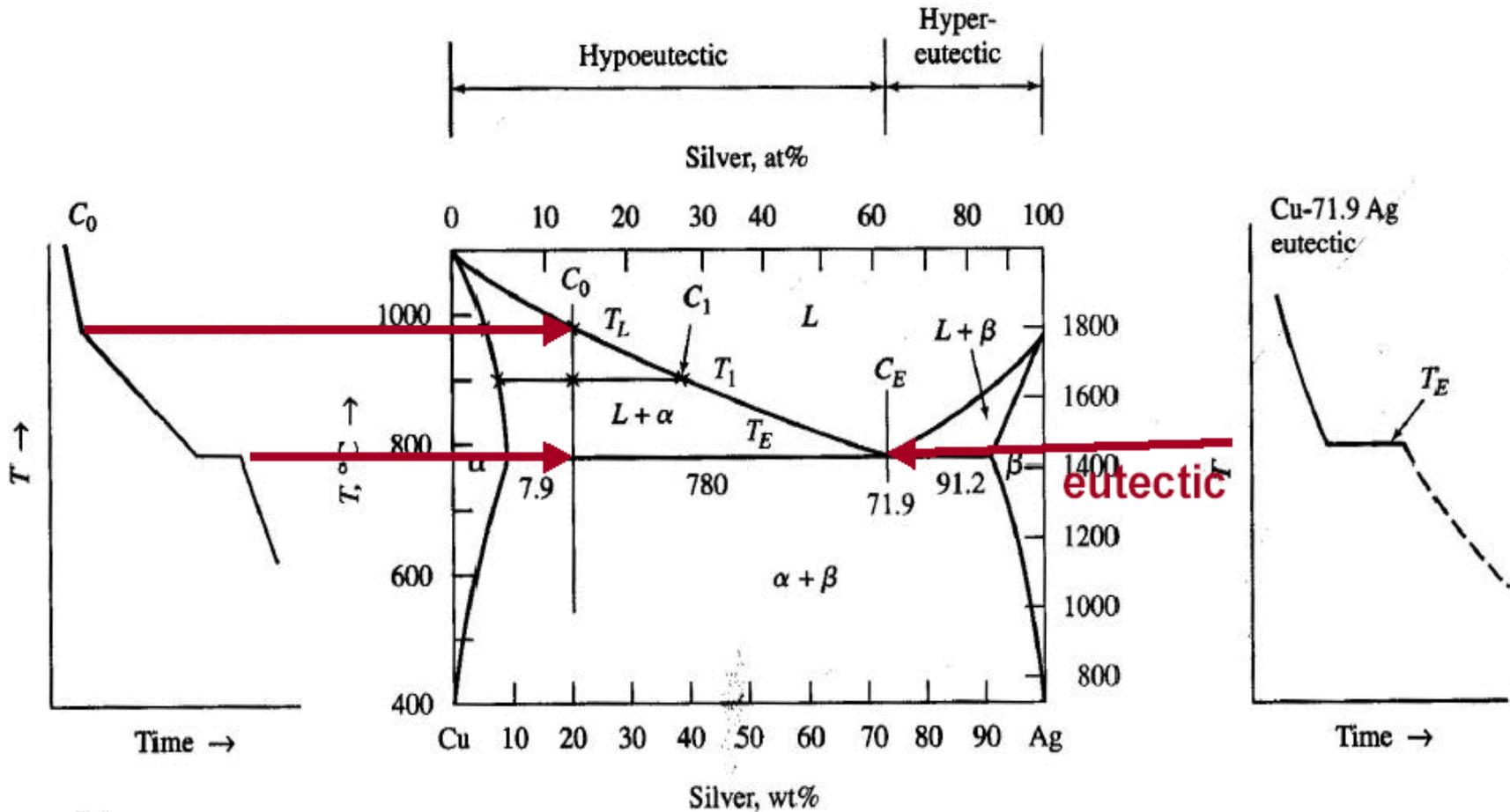
Solución sólida α + solución sólida β

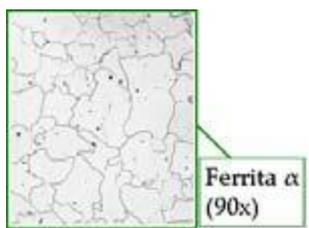
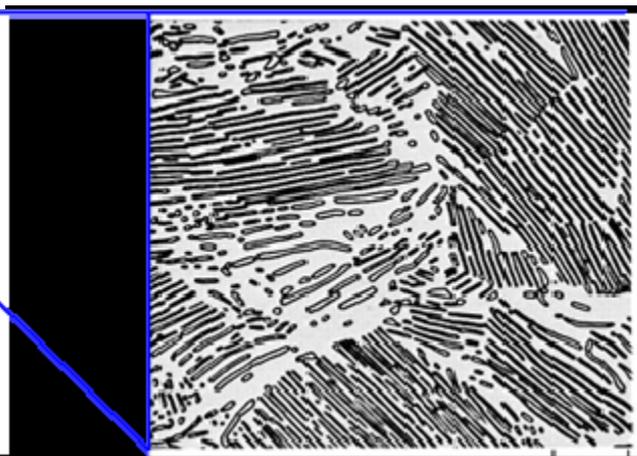
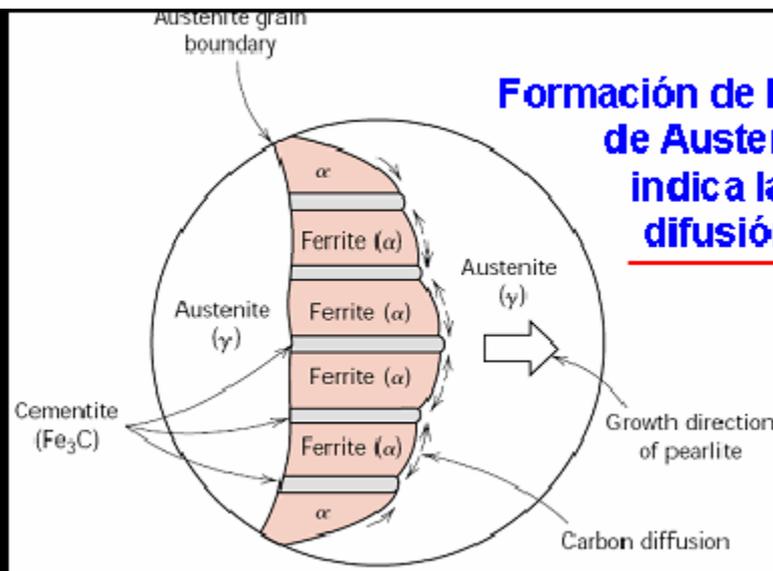
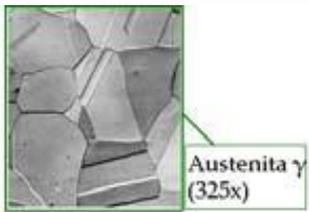
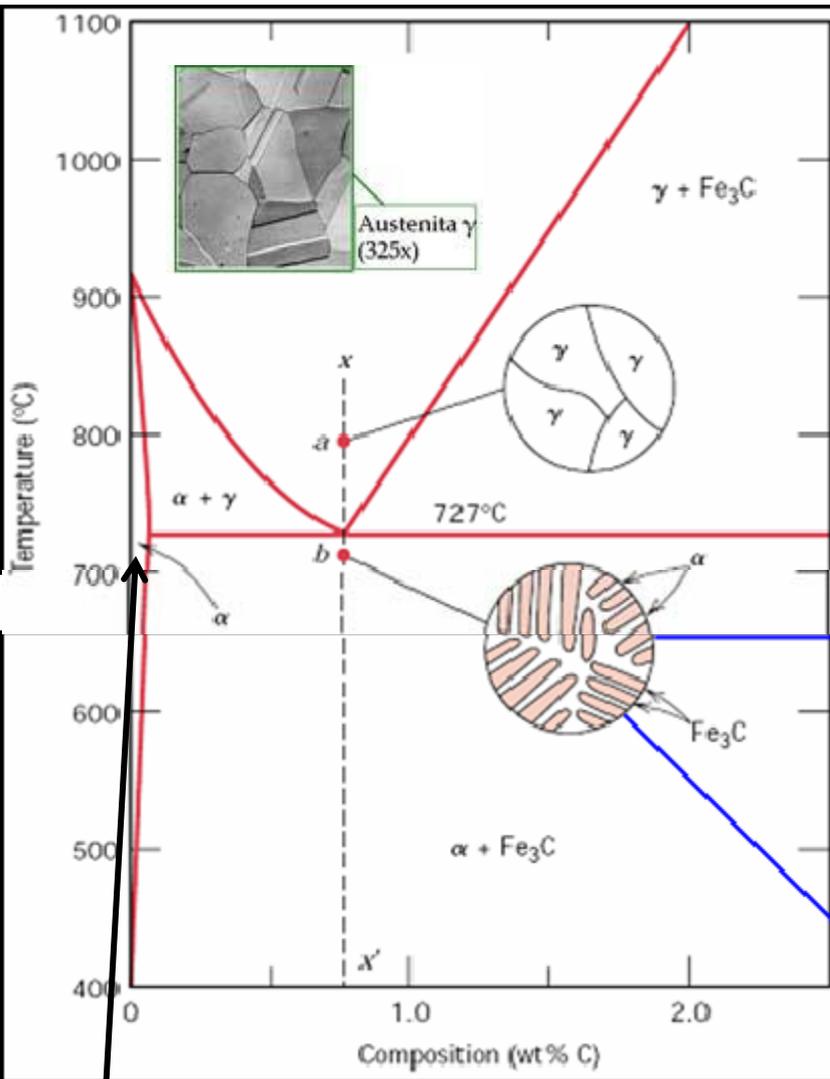




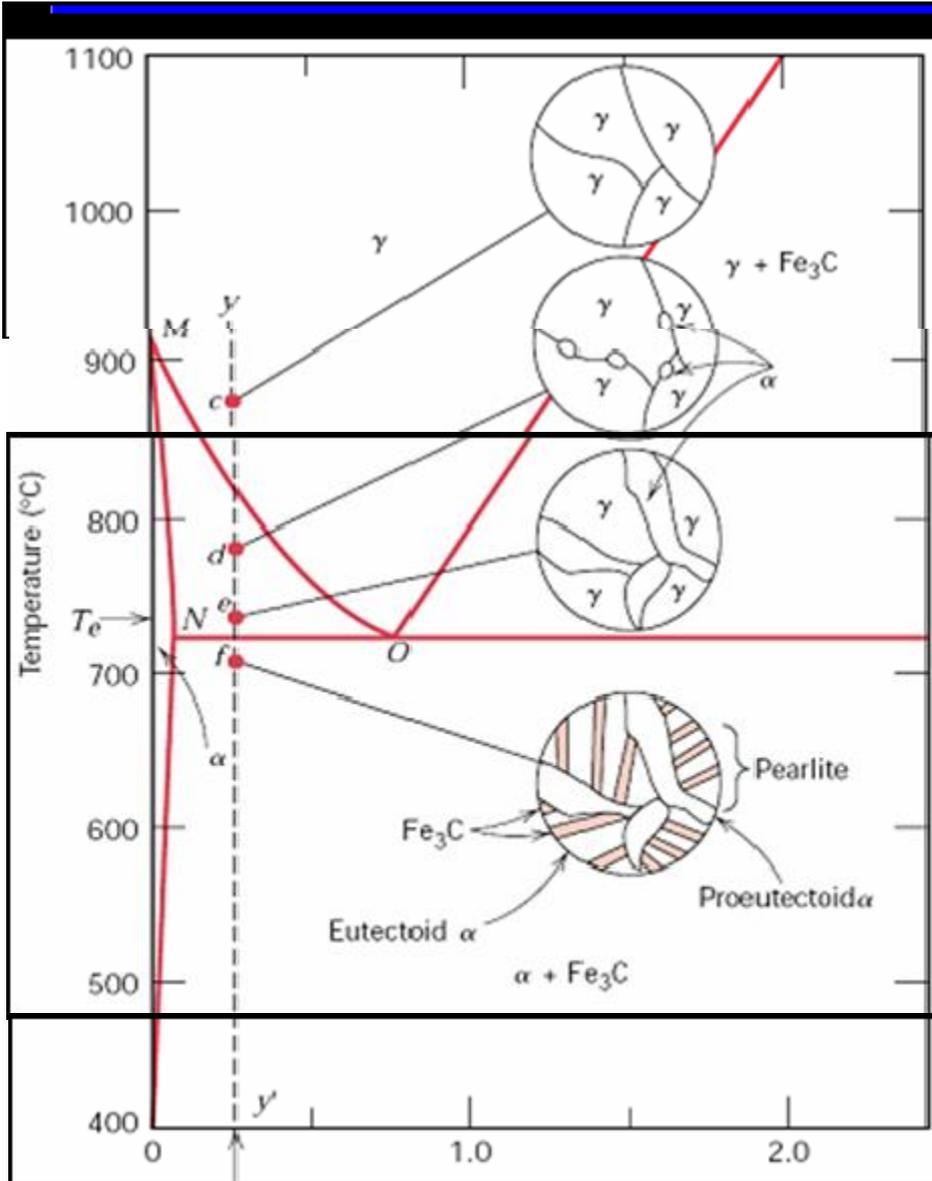
Curva esquemática Temperatura-Tiempo de enfriamiento de una aleación con 60% de Pb y 40% de Sn

Eutética Cu-Ag

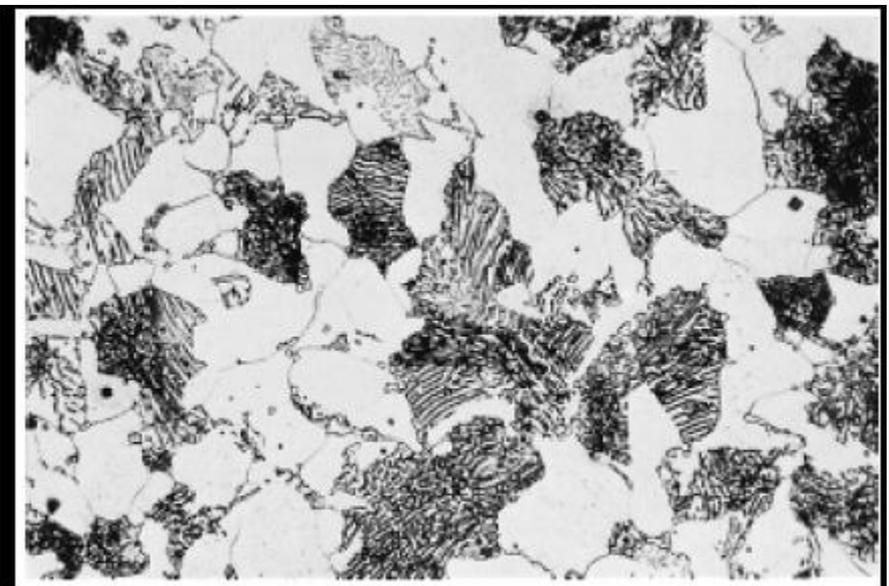




Microestructuras para una aleación Fe-C de composición eutectoide (0,76% C) por encima y debajo de la temperatura eutectoide.



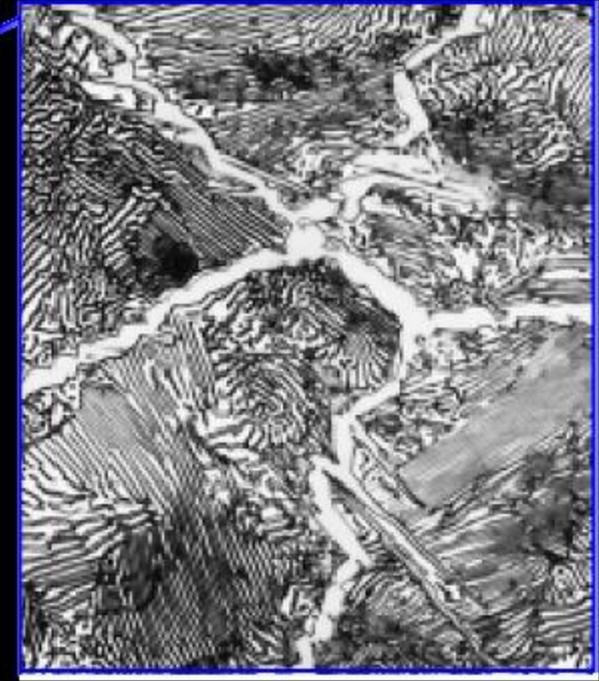
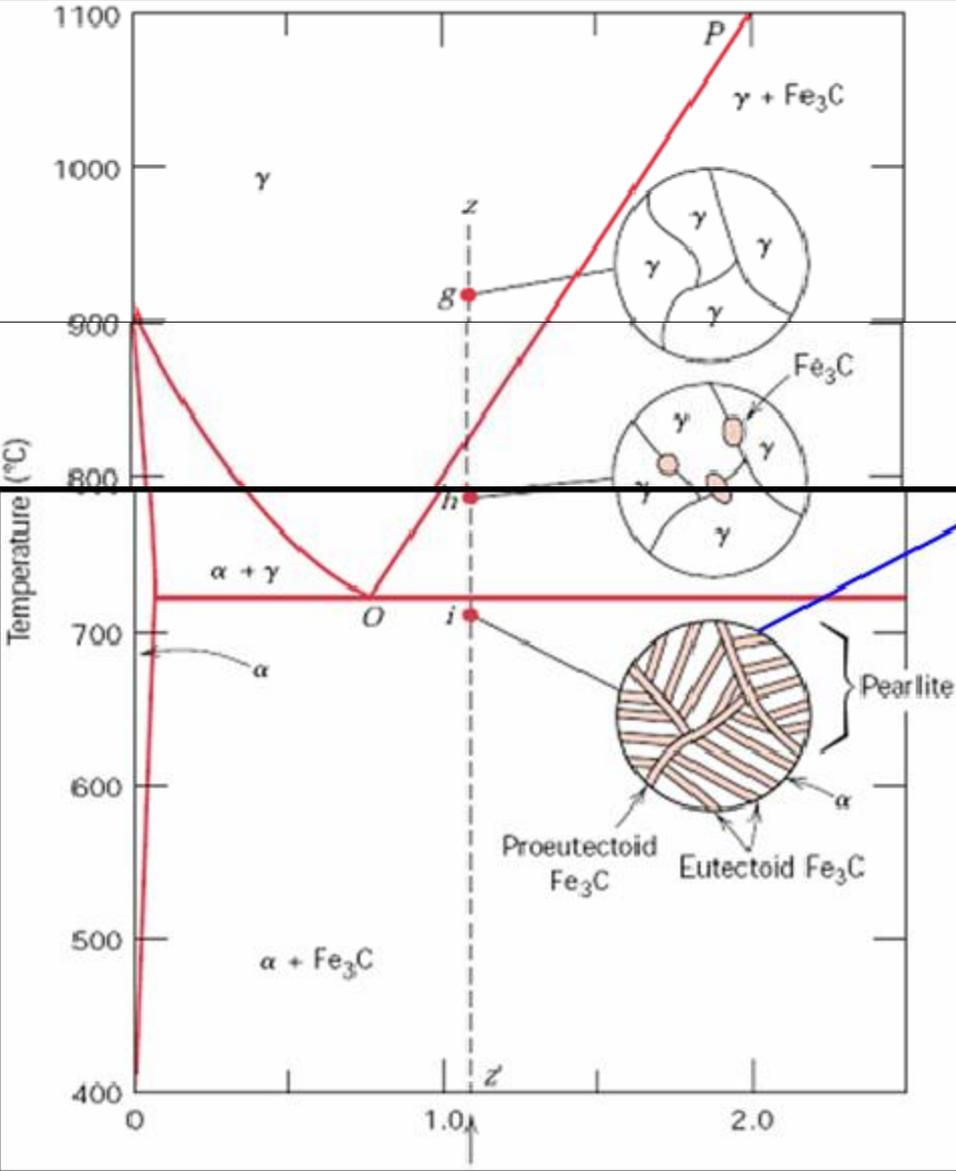
Microestructuras para una aleación Fe-C de composición hipoeutectoide Co (conteniendo menos de 0,76% C) mientras es enfriada desde la fase de austenita hasta por debajo de la temperatura eutectoide



Fotomicrografía de un acero de 0,38% C con una microestructura que consiste en perlita y ferrita proeutectoide. 635x

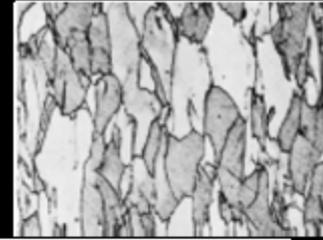
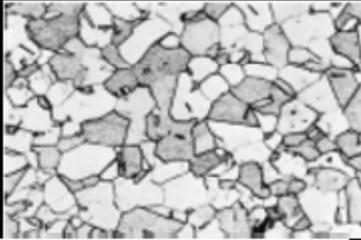
Microestructuras para una aleación Fe-C de composición hipoeutectoide por encima y debajo de la temperatura eutectoide.

Microestructuras para una aleación Fe-C de composición hipereutectoide C₁ (conteniendo entre 0,76 y 2,14 %C) mientras es enfriada desde la fase de austenita hasta por debajo de la temperatura eutectoide

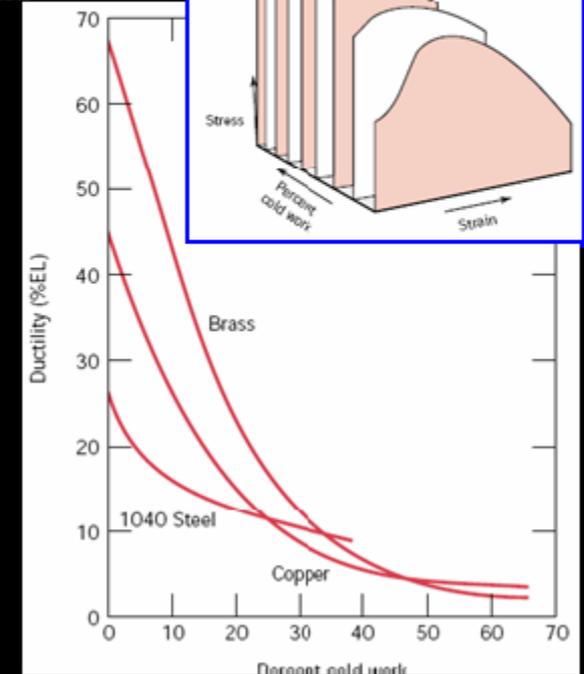
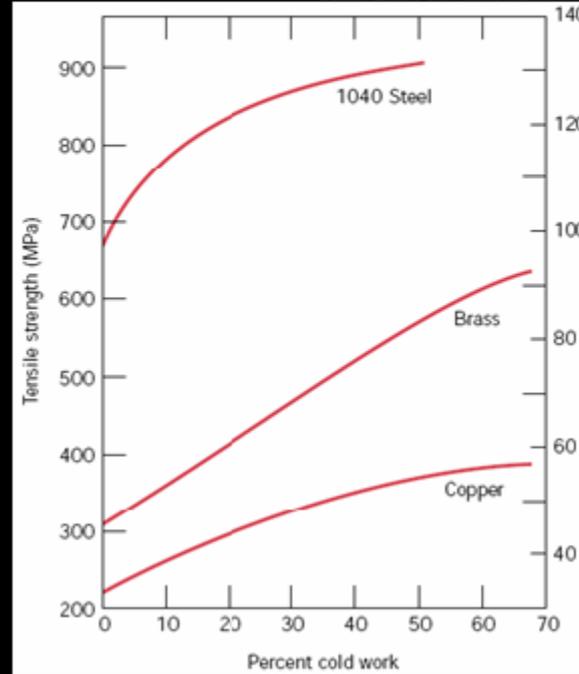
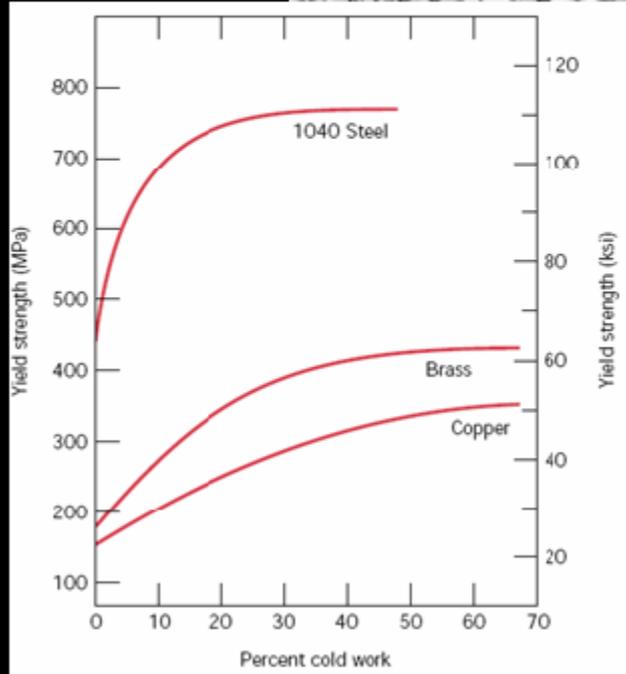
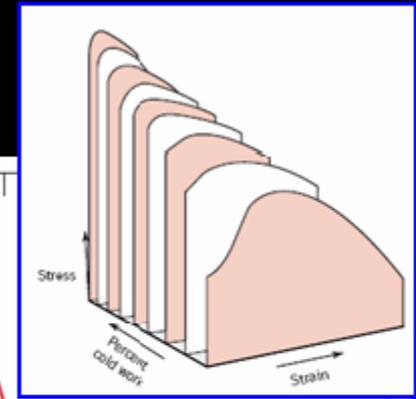


Microestructuras para una aleación Fe-C de composición hipereutectoide por encima y debajo de la temperatura eutectoide.

Granos antes de trabajo en frío



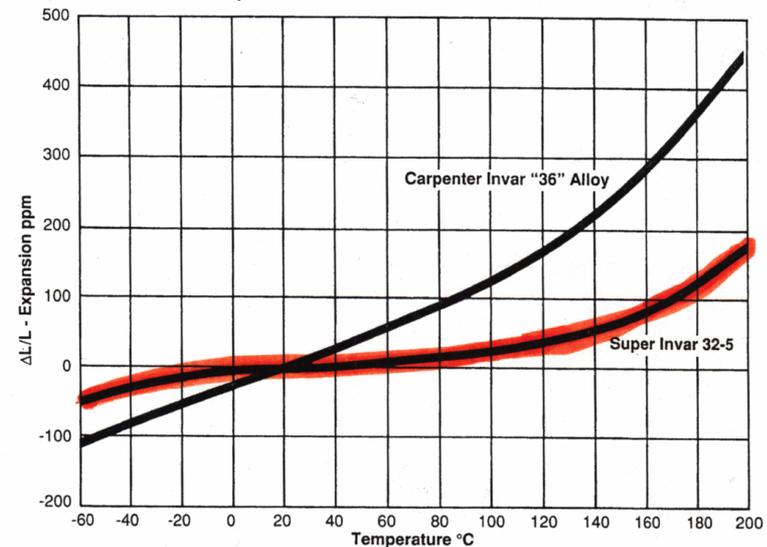
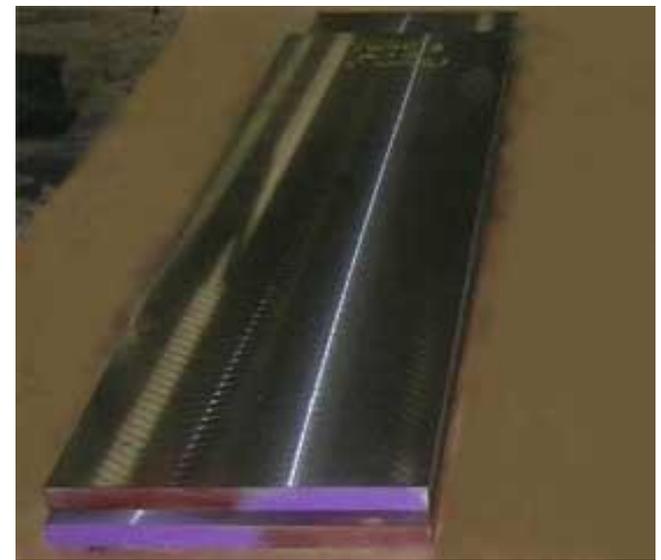
Granos elongados



Incremento del Esfuerzo de cedencia, Incremento del Esfuerzo tensil y Decremento de la ductilidad con el porcentaje de trabajo en frío para Acero 1040, Latón Cu-Zn (Brass) y Cobre

Efecto del endurecimiento por deformación (trabajo en frío) de un material sobre las propiedades mecánicas

Aleaciones de expansión térmica nula o negativa



Expansión térmica

- ¿Qué es la expansión térmica?
- Importancia de la expansión térmica
 - Materiales expuestos a cambios de temperatura
- Comportamiento común de los metales
 - Calor ➤ Expansión

Expansión térmica nula

- Calor ➤ sin cambios
- Estabilidad dimensional en el diseño
- Estructuras espaciales, puentes y sistemas de tuberías
- Se busca la distribución óptima de ambos materiales

-
-
- microestructura hipotética óptima de dos materiales.
Las partes rojas son de alta expansión, las azules de baja expansión y las blancas son vacío.
-

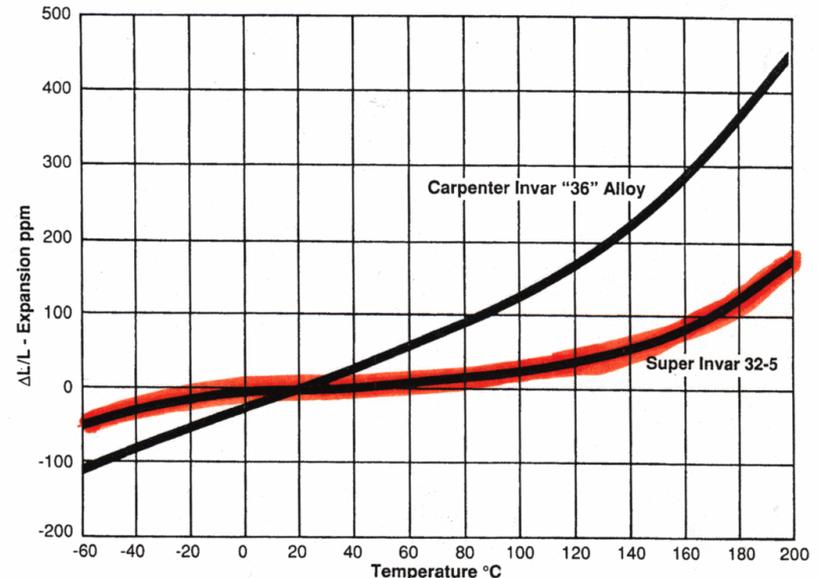
Aleación Itrio-Galio-Germanio

- Exhibe ZTE
- Valencia inducida
- Necesario para reducir estrés



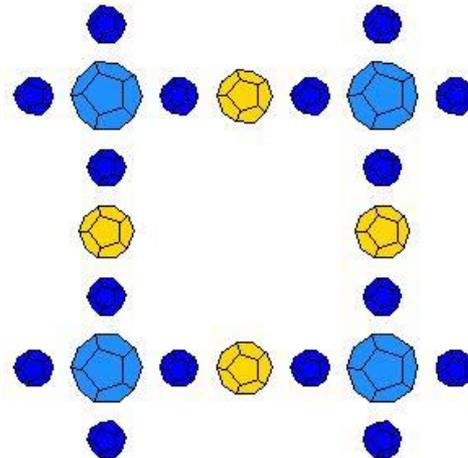
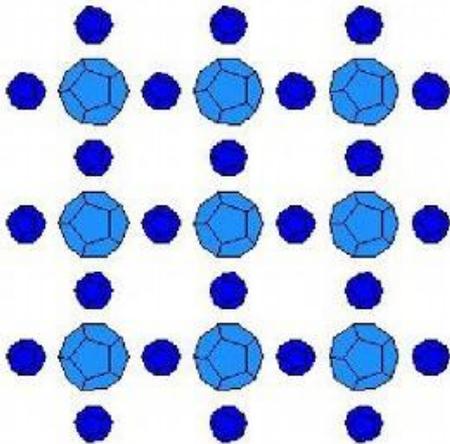
Aleación Super-Invar (Fe-Ni-Co)

- Diseñada para proveer una expansión térmica casi nula
 - Temperaturas entre -35 °C y 135 °C
- Tratamiento térmico
 - Genera el menor coef. de expansión térmica
 - Aleación resistente y blanda
- Aplicación en instrumentos de precisión

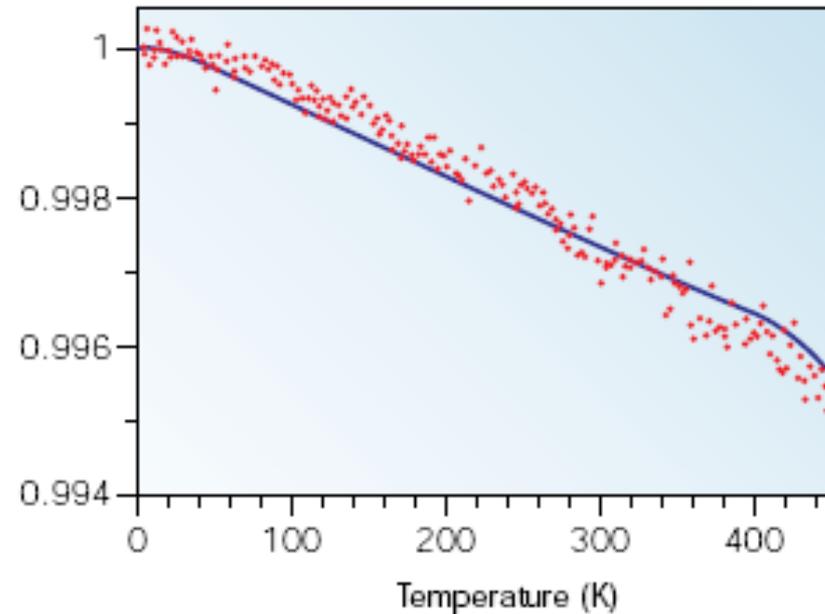
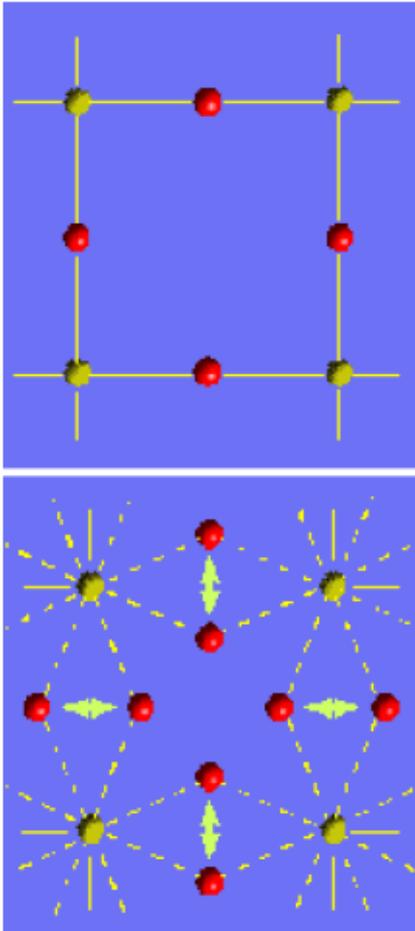


Expansión térmica negativa

- Expansión térmica negativa
 - Calor ➤ contracción
- Aplicaciones
 - Uniones de piezas
- Consideraciones inusuales de entropía

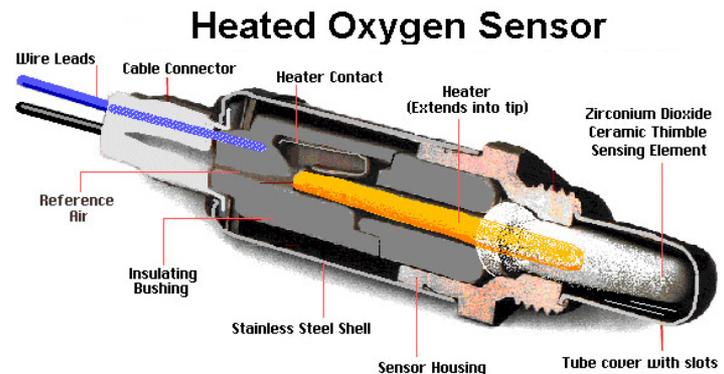
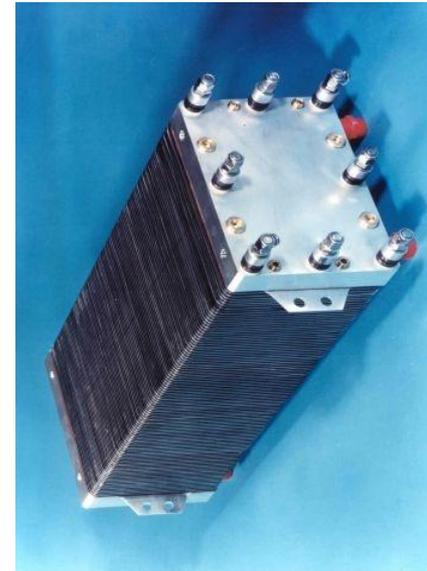


Tungstato de circonio (ZrW_2O_8)



Tungstato de circonio (ZrW_2O_8)

- Aplicaciones
 - Electrónica
 - Celdas de combustible
 - Sensores
 - Termostatos
 - Odontología



Aleación magnesio-itrrio

- Resistente a la corrosión
- Efecto del CO_2
- Formación de películas de hidroxicarbonato
- Se utiliza en aviación

