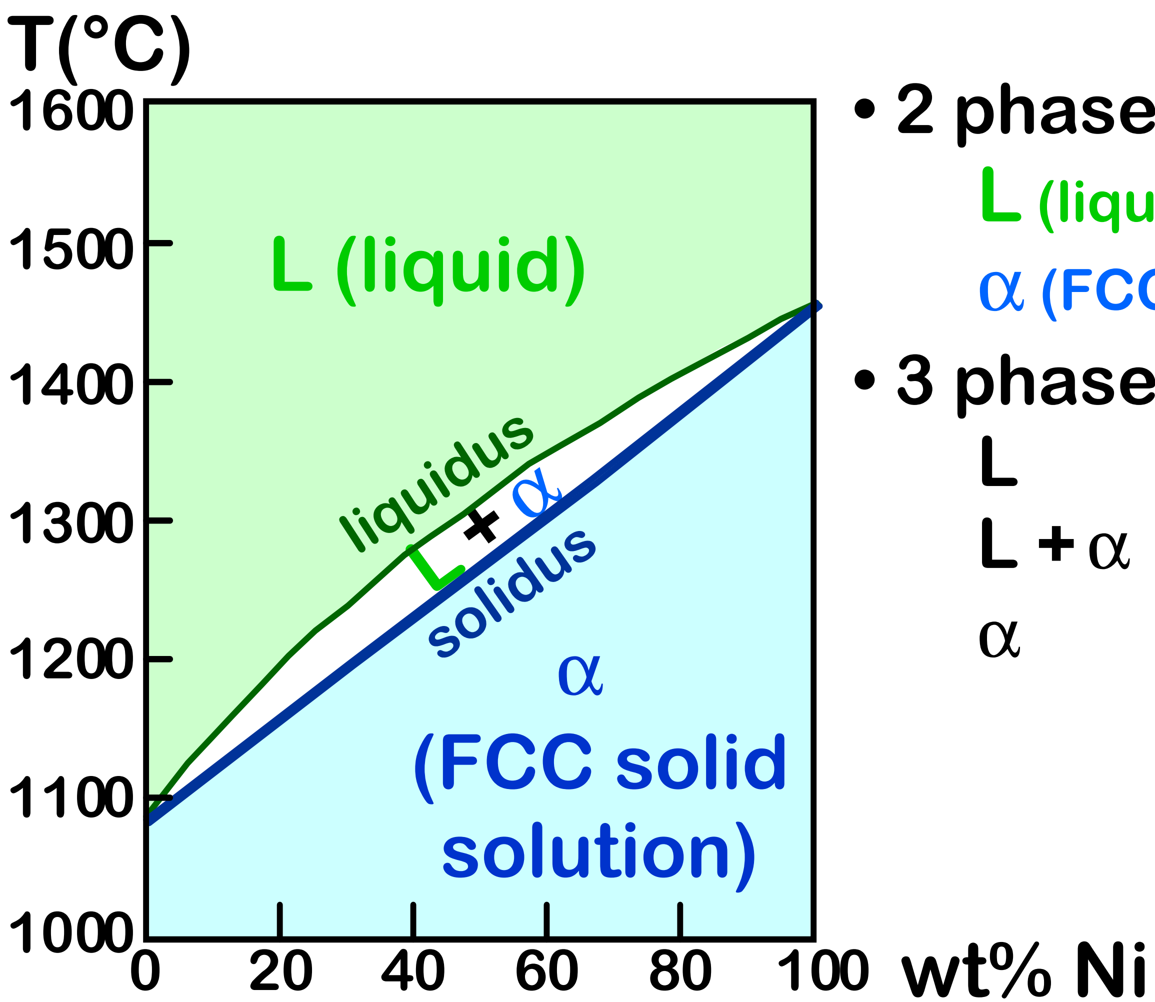
PHASE DIAGRAM

BY

ENGR. MS TAYYABA BANO

Cu-Ni System



- 2 phases:
  - L (liquid)
  - α (FCC solid solution)
- 3 phase fields:
  - L
  - L + α
  - α

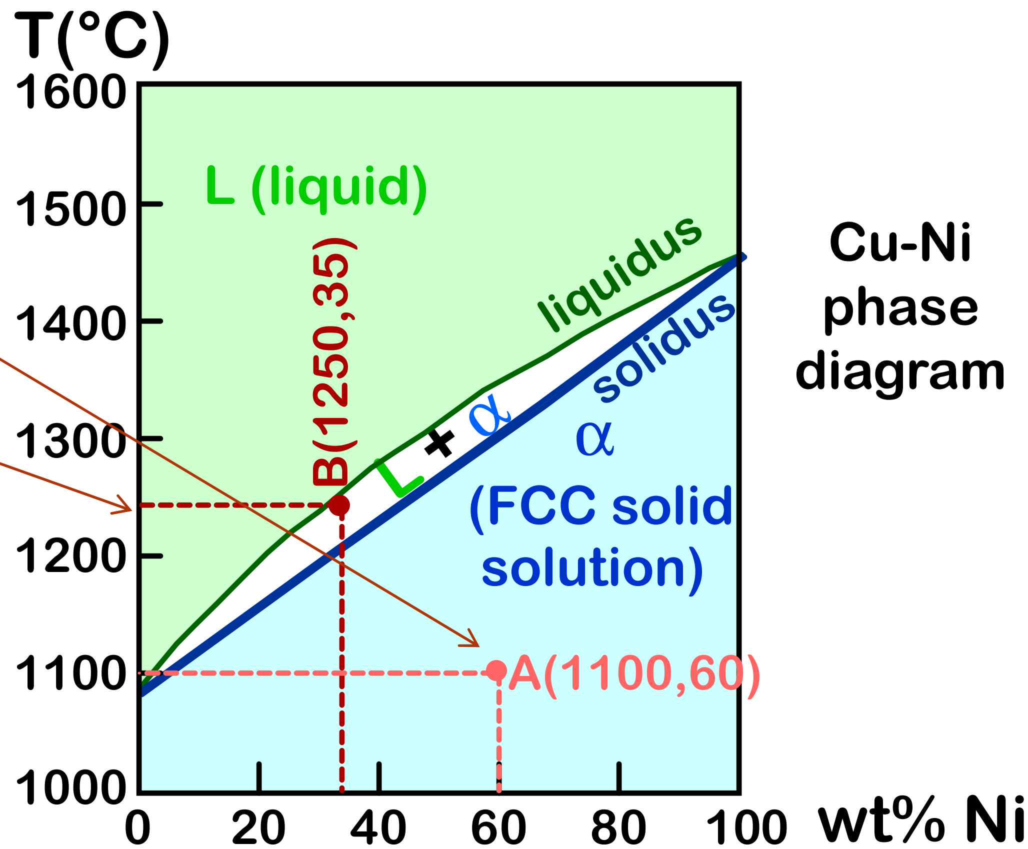
PHASE DIAGRAMS: # and types of phases

- **Rule 1**: If we know T and C_o, then we know:
  the <u># and types of phases present</u>.

- Examples:

  A(1100, 60):
  1 phase: α

  B(1250, 35):
  2 phases: L + α



PHASE DIAGRAMS: composition of phases

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

- Examples:

C_o = 35wt%Ni

At T_A:

Only Liquid (L)

$C_L = C_o$ (= 35wt% Ni)

At T_D:

Only Solid (α)

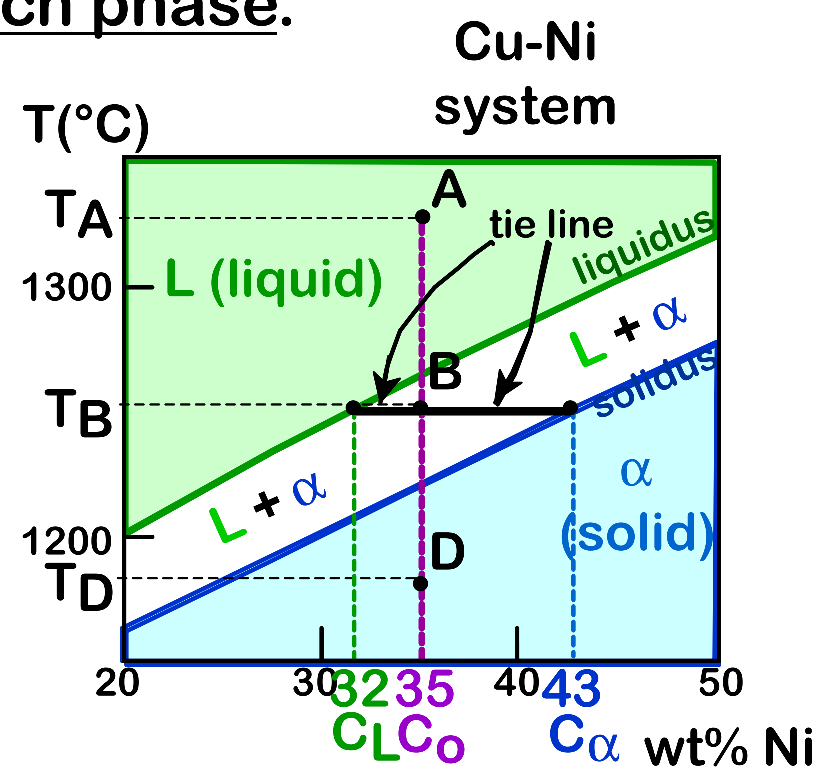
$C_\alpha = C_o$ (= 35wt% Ni)

At T_B:

Both α and L

$C_L = C_{liquidus}$ (= 32wt% Ni here)

$C_\alpha = C_{solidus}$ (= 43wt% Ni here)



PHASE DIAGRAMS: weight fractions of phases

Rule 3: If we know T and C_o, then we know: the amount of each phase (given in wt%).

- Examples:

C_O = 35wt%Ni

At T_A: Only Liquid (L)

W_L = 100wt%, W_α = 0

At T_D: Only Solid (α)

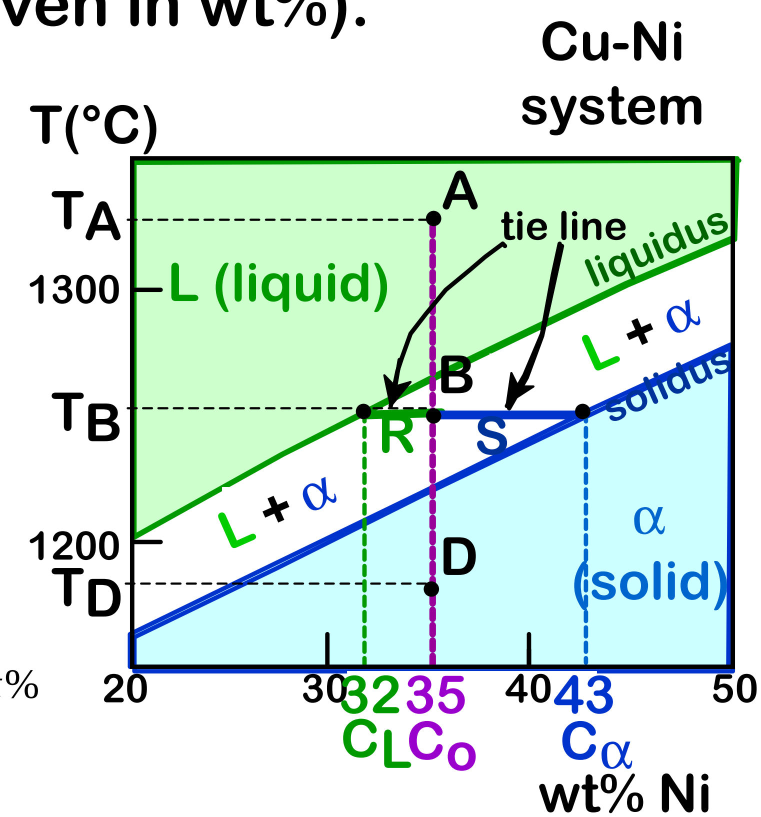
W_L = 0, W_α = 100wt%

At T_B: Both α and L

$$W_L = \frac{S}{R+S} = \frac{C_\alpha - C_0}{C_\alpha - C_L} = \frac{43-35}{43-32} = 73wt\%$$

$$W_\alpha = \frac{R}{R+S} = 27wt\%$$

$$= \frac{C_o - C_\alpha}{C_\alpha - C_L} = 27\ wt\ \%$$



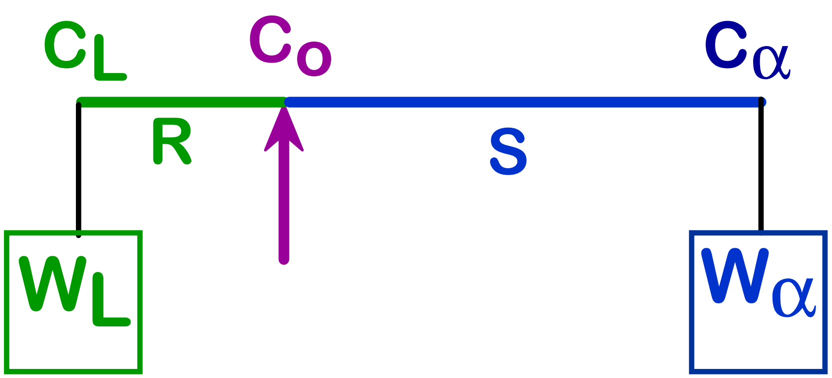
THE LEVER RULE: A PROOF

- Sum of weight fractions: $W_L + W_\alpha = 1$
- Conservation of mass (Ni): $C_o = W_L C_L + W_\alpha C_\alpha$
- Combine above equations:

$$W_L = \frac{C_\alpha - C_o}{C_\alpha - C_L} = \frac{S}{R + S}$$

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

- A geometric interpretation:



moment equilibrium:

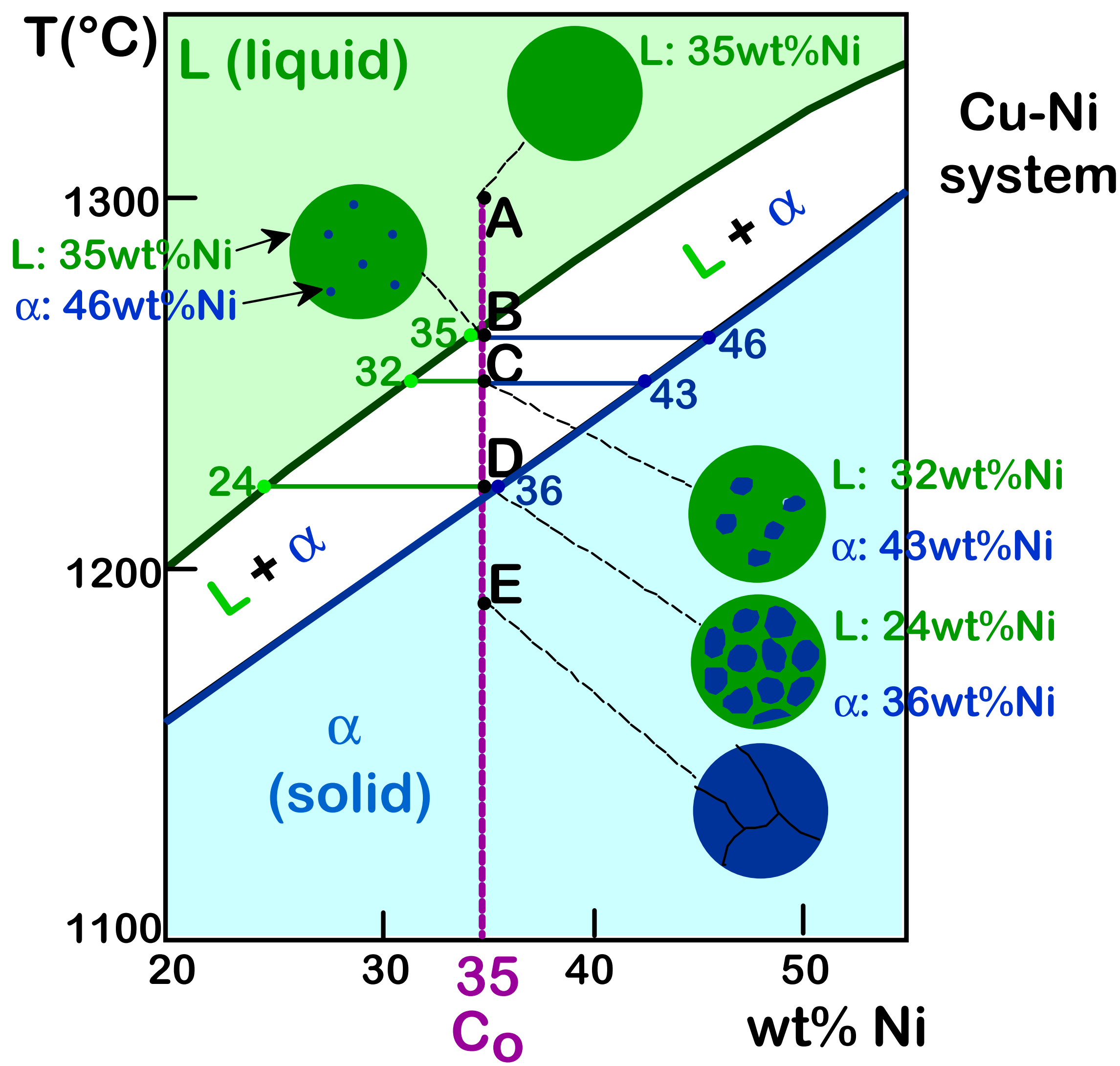
$$W_L R = W_\alpha S$$

$$1 - W_\alpha$$

solving gives Lever Rule

COOLING IN A Cu-Ni BINARY

- **Phase diagram:**
  Cu-Ni system.
- **System is:**
  --binary
  ***i.e.*, 2 components:** **Cu and Ni.**
  --isomorphous
  i.e., complete solubility of one component in another; α phase field extends from 0 to 100wt% Ni.
- **Consider**
  C_o = 35wt%Ni.



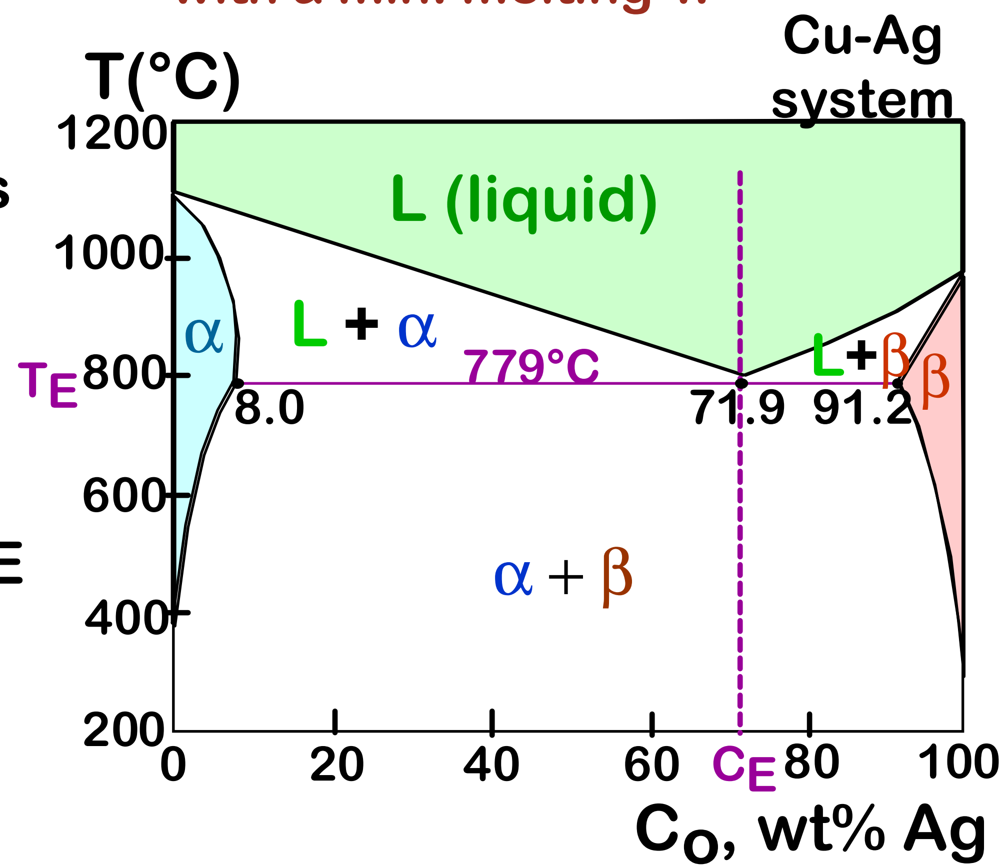
BINARY-EUTECTIC SYSTEMS

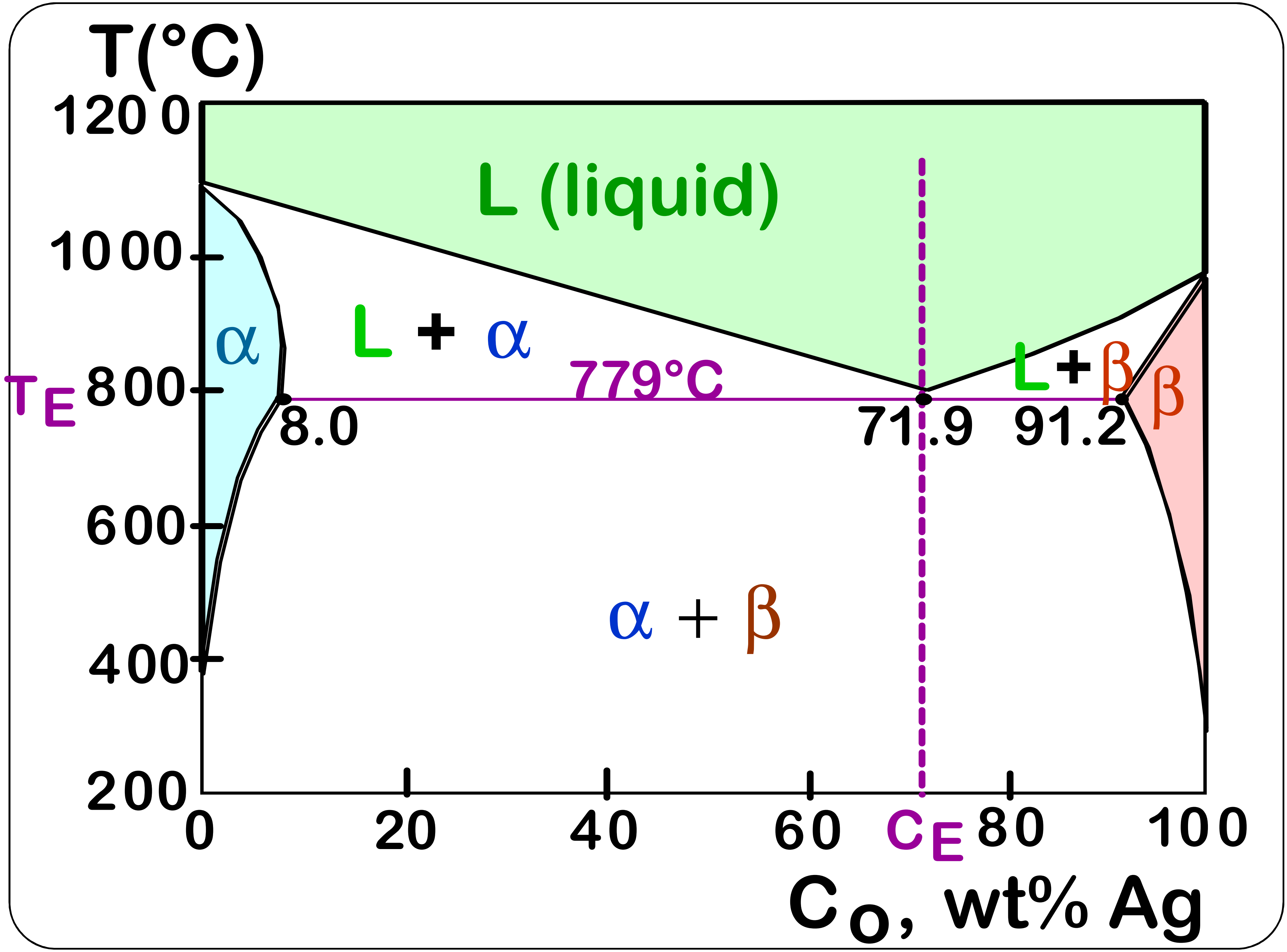
2 components

has a special composition with a min. melting T.

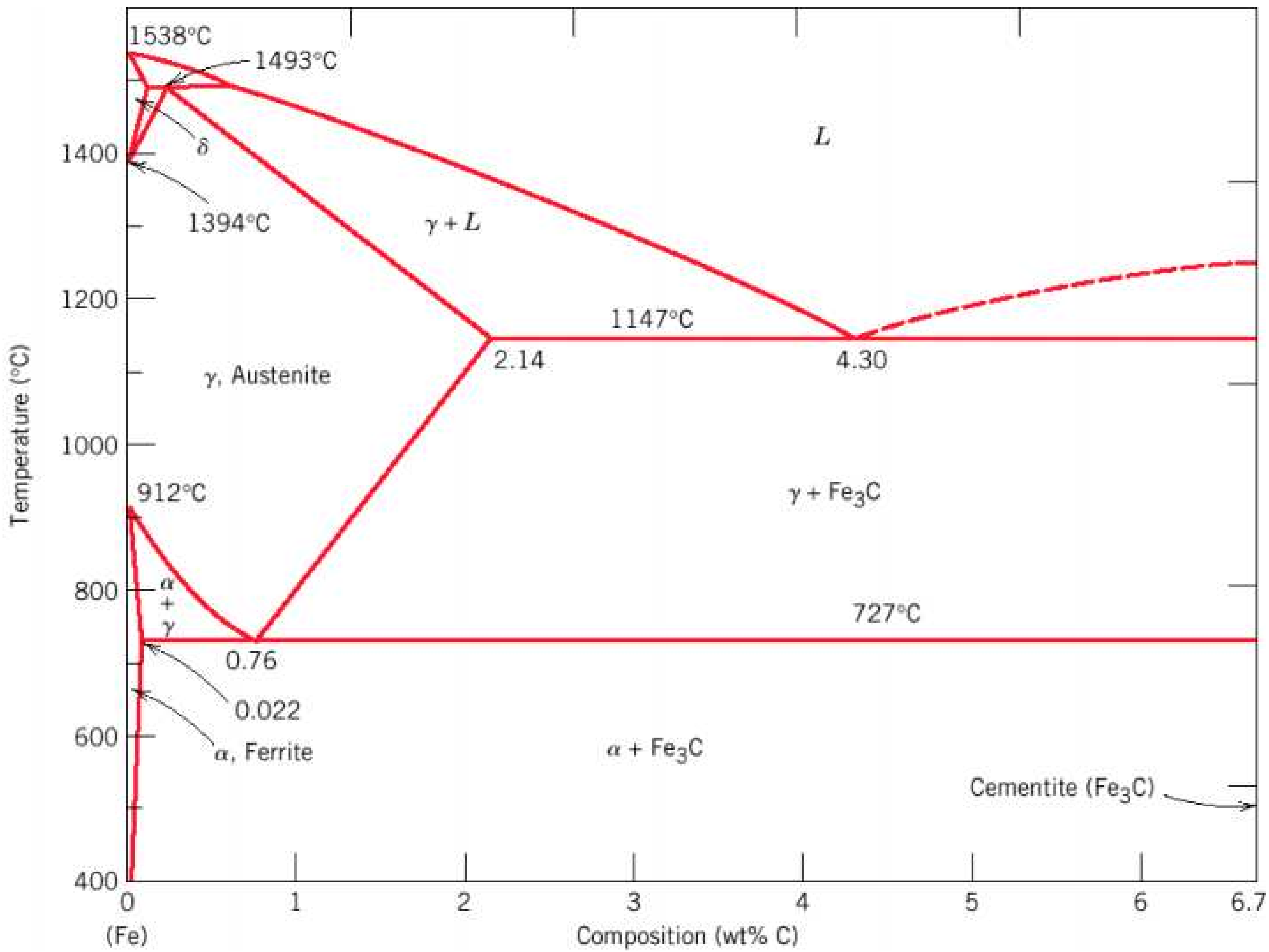
Ex.: Cu-Ag system

- 3 single phase regions (L, α, β)
- Limited solubility:
  - α: mostly Cu
  - β: mostly Ni
- T_E: No liquid below T_E
- C_E: Min. melting T composition




T(°C)
1200
1000
800
600
400
200
L (liquid)
α
L + α
779°C
L+β
β
T_E
8.0
71.9
91.2
α + β
0
20
40
60
C_E
80
100
C_o, wt% Ag

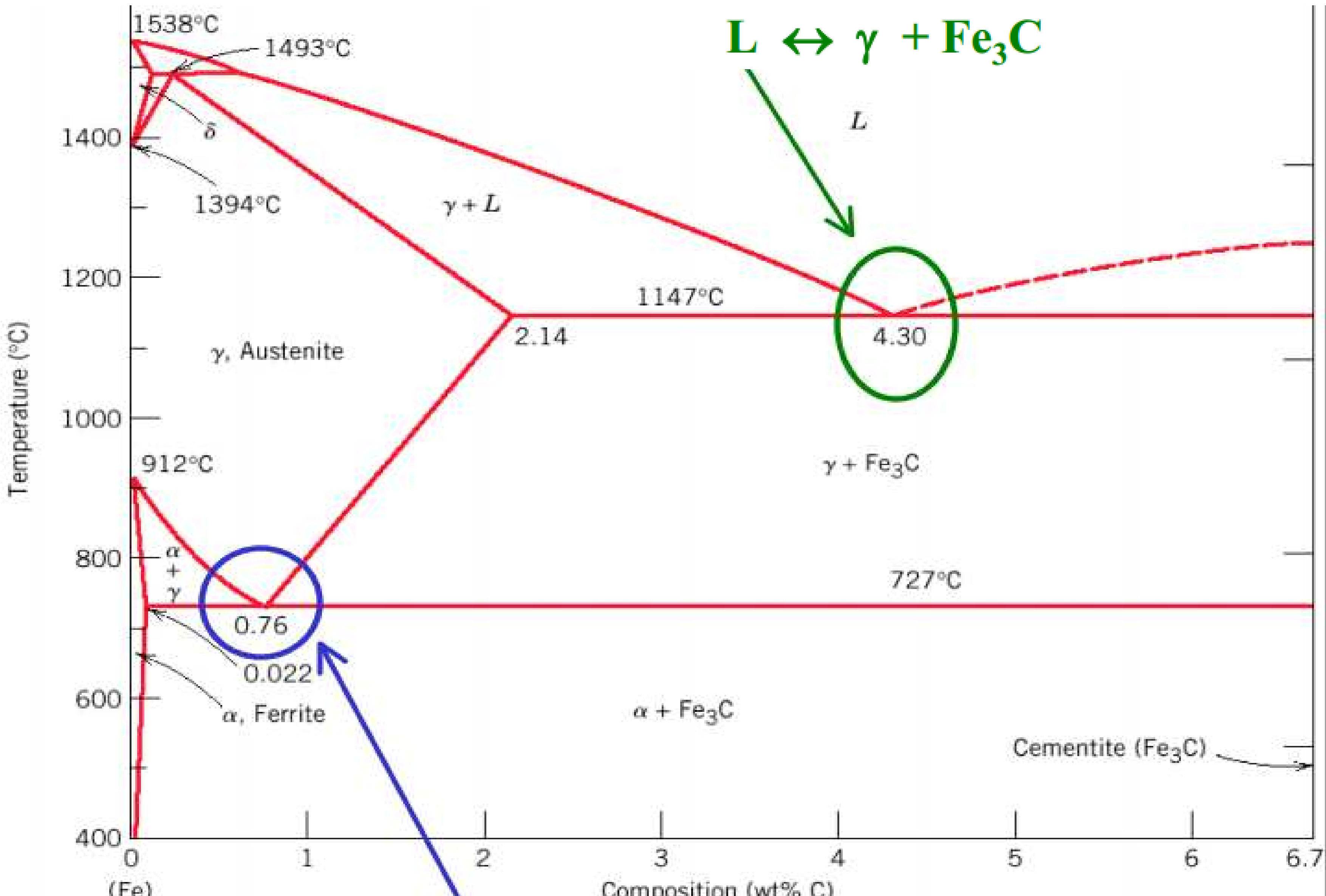
IRON-CARBON/ SYSTEM/ PHASE DIAGRAM



1538°C
1493°C
L
δ
1400
1394°C
γ + L
1200
1147°C
2.14
4.30
γ, Austenite
1000
912°C
γ + Fe3C
800
α
+
γ
727°C
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
400
0
(Fe)
1
2
3
4
5
6
6.7
Temperature (°C)
Composition (wt% C)

Eutectic: 4.30 wt% C, 1147 °C

$L \leftrightarrow \gamma + Fe_3C$

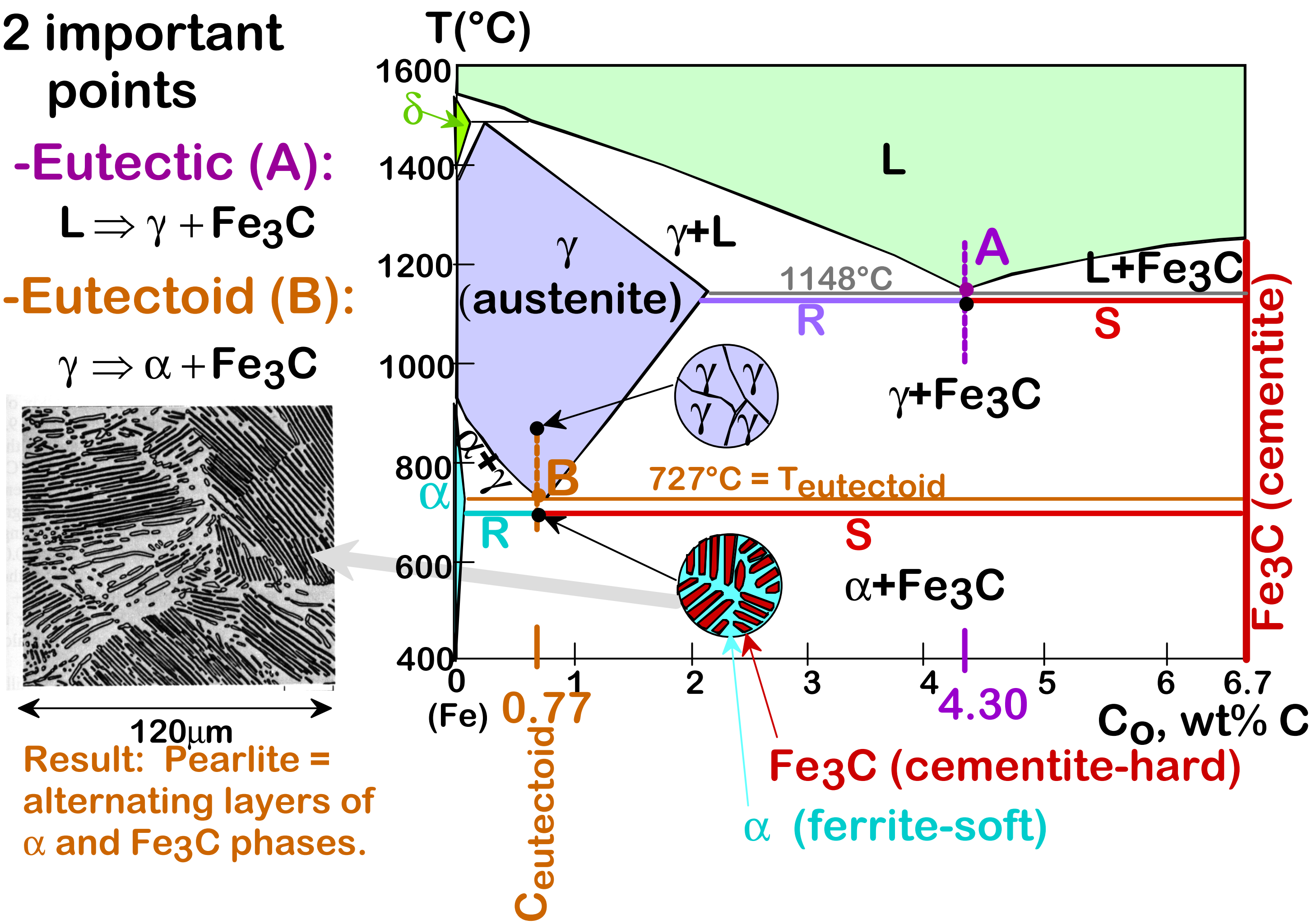


Eutectoid: 0.76 wt%C, 727 °C

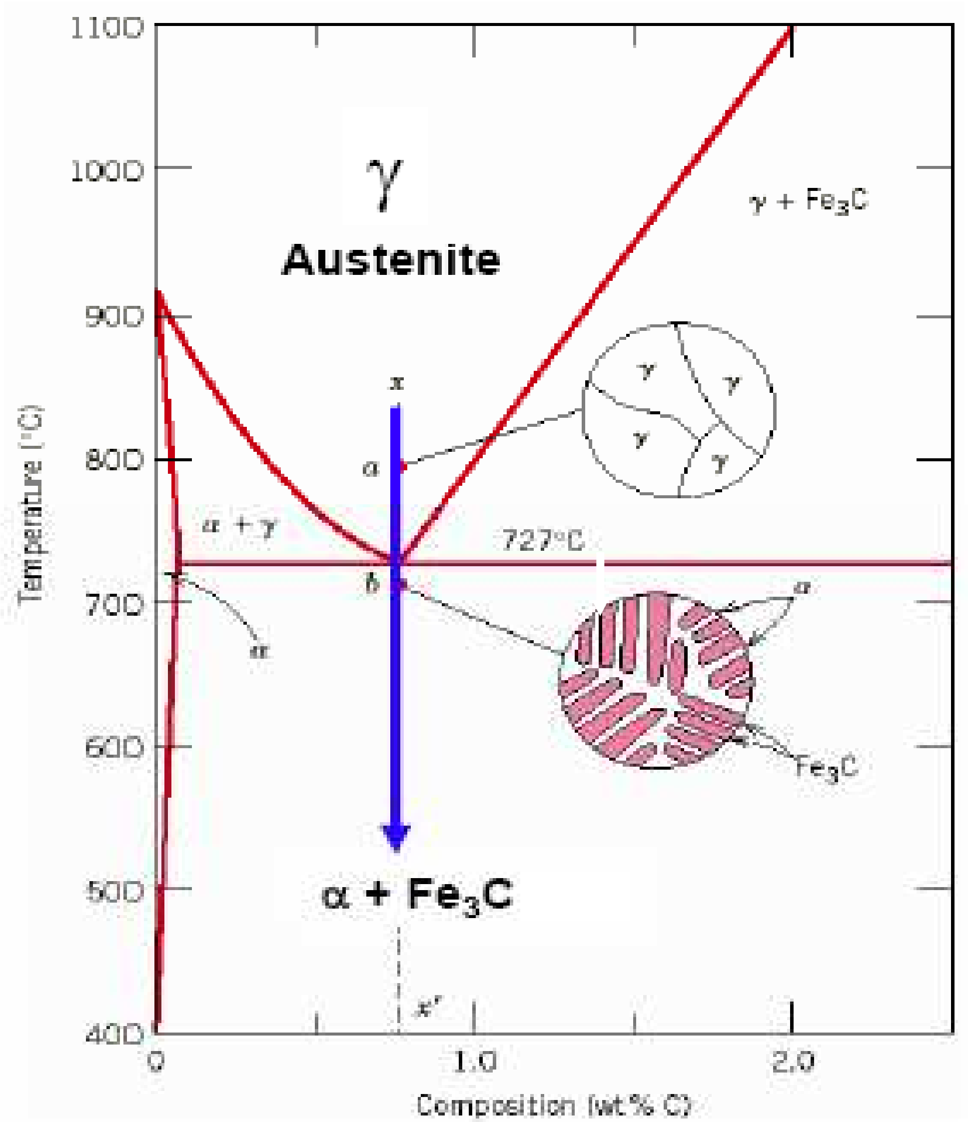
γ(0.76 wt% C) $\leftrightarrow$ α (0.022 wt% C) + Fe_3C

IRON-CARBON (Fe-C) PHASE DIAGRAM

- 2 important points
  - -Eutectic (A): $L \Rightarrow \gamma + Fe_3C$
  - -Eutectoid (B): $\gamma \Rightarrow \alpha + Fe_3C$



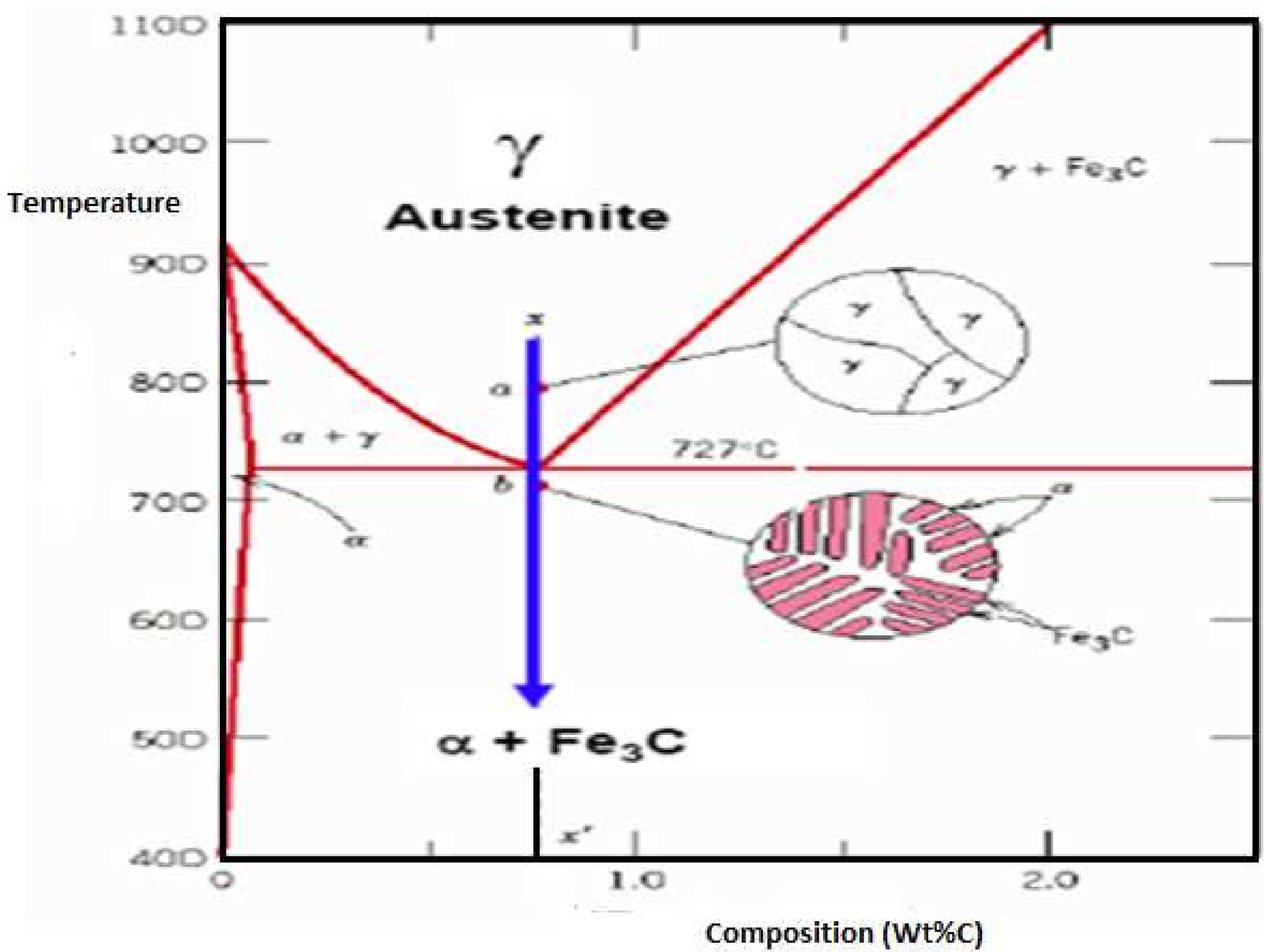
DEVELOPMENT OF MICROSTRUCTURES



- Austenite precipitates **Fe_3C** at Eutectoid Transformation Temperature (727°C).

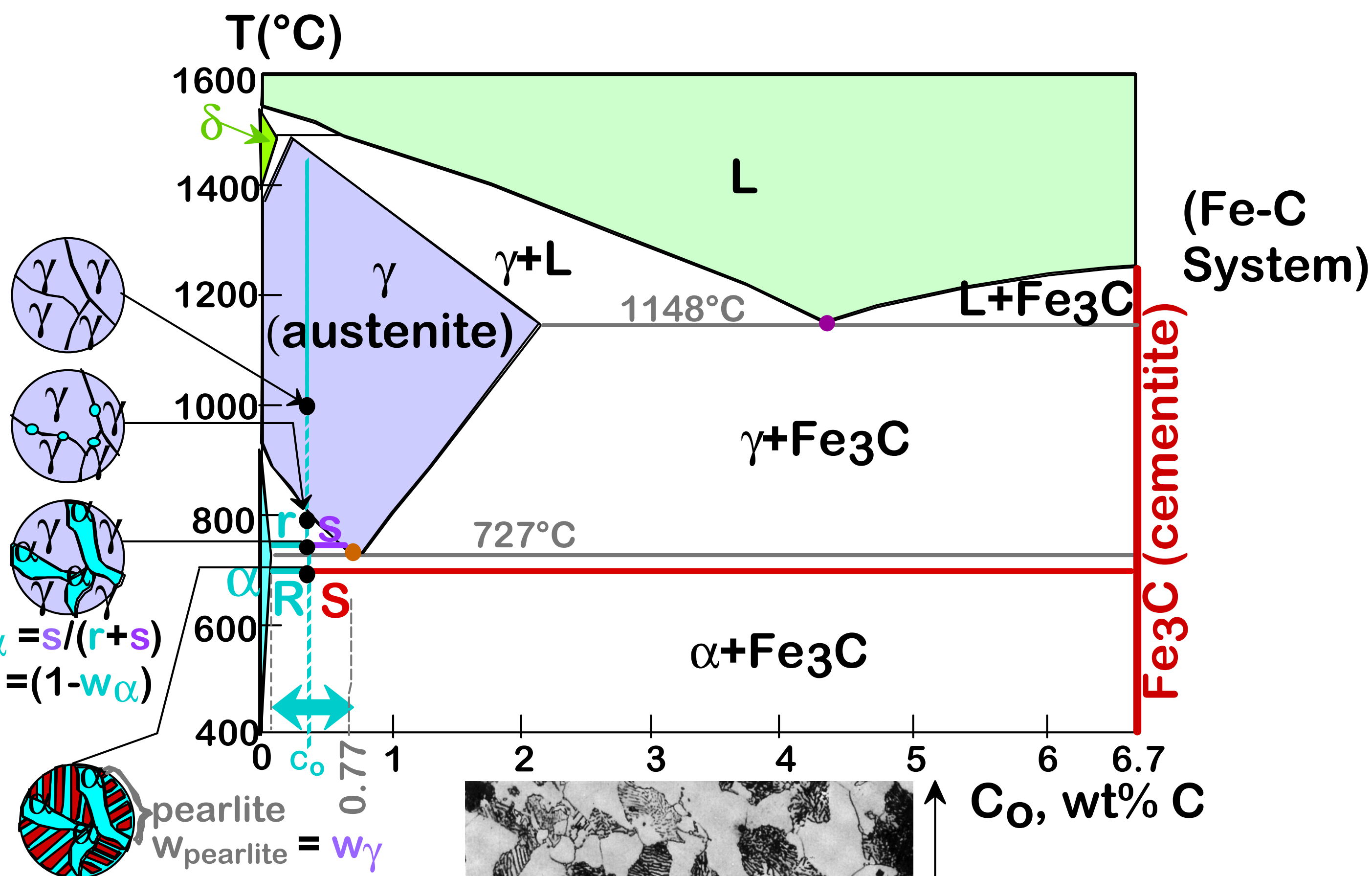
$$\gamma \underset{\text{Heating}}{\overset{\text{Cooling}}{\longleftrightarrow}} \alpha + \mathbf{Fe_3C}$$

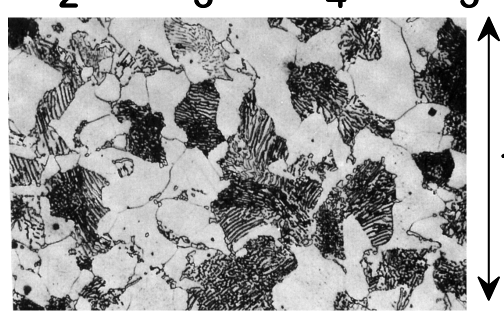
- When cooled slowly, forms Pearlite, which is a micro-contituent made of ferrite (α) and Cementite (**Fe_3C**),



1100
1000
900
800
700
600
500
400
Temperature
γ
Austenite
γ + Fe3C
x
a
α + γ
727°C
b
α
α
Fe3C
α + Fe3C
x'
0
1.0
2.0
Composition (Wt%C)

HYPOEUTECTOID STEEL





$w_\alpha = S/(R+S)$

$w_{Fe3C} = (1 - w_\alpha)$

Adapted from Fig. 9.27, *Callister 6e*. (Fig. 9.27 courtesy Republic Steel Corporation.)

HYPO-EUTECTOID

Hypo-eutectoid Composition (wt% C <0.76)

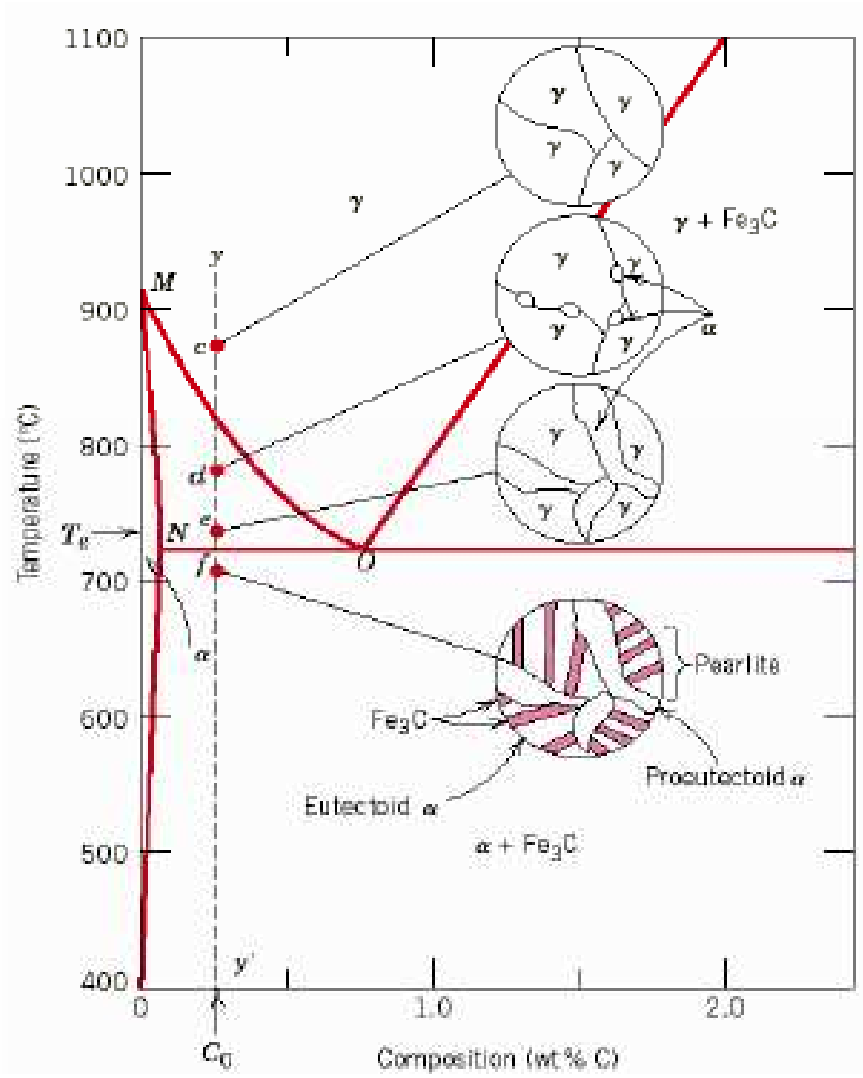
- Composition 0.002 and 0.76 wt% C
- Upon cooling enter a two-phase region

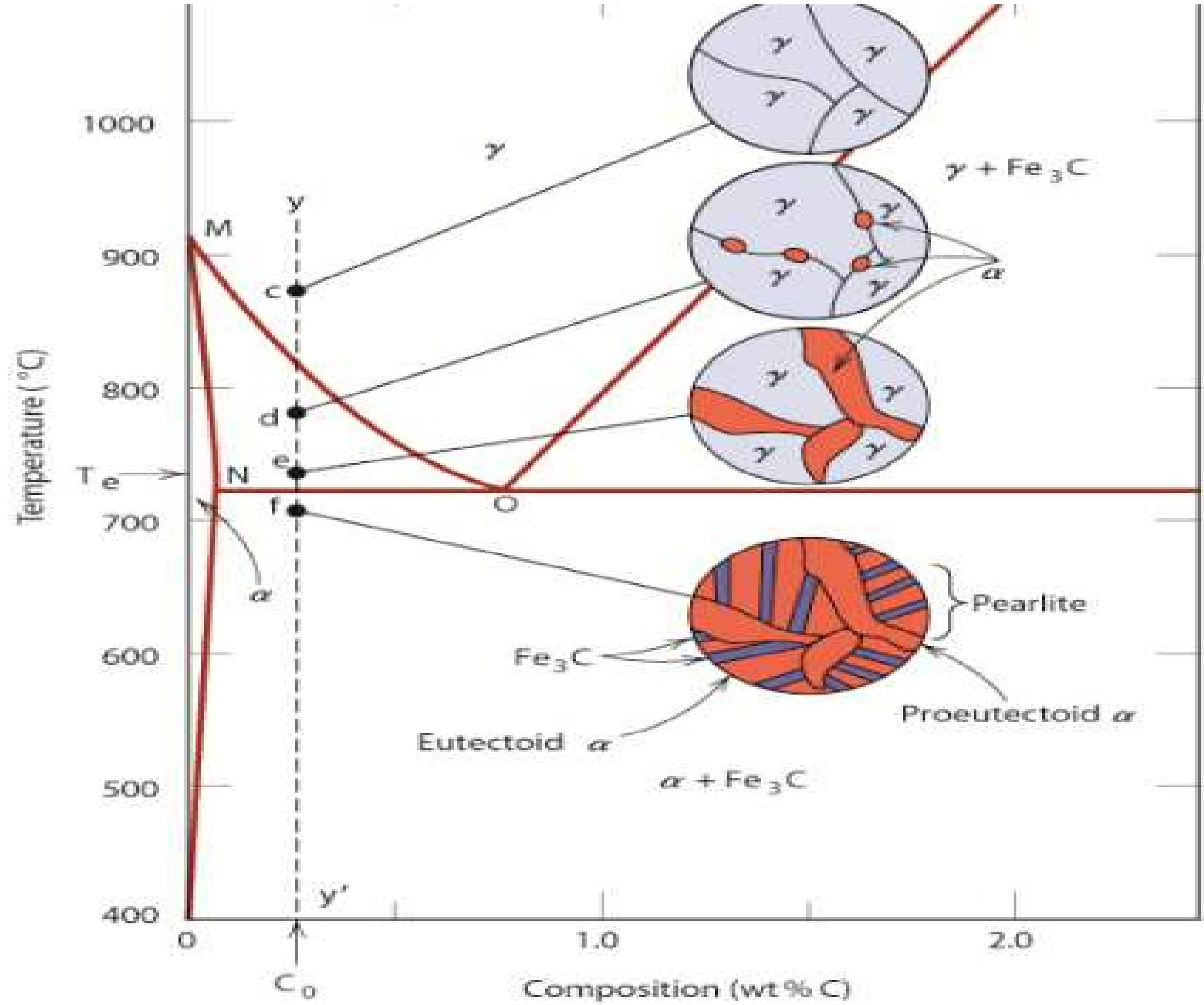
$$\gamma \Rightarrow \alpha + \gamma$$

- Below 727°C the remaining austenite transforms to pearlite

$$\gamma \Rightarrow \alpha + Fe_3C$$

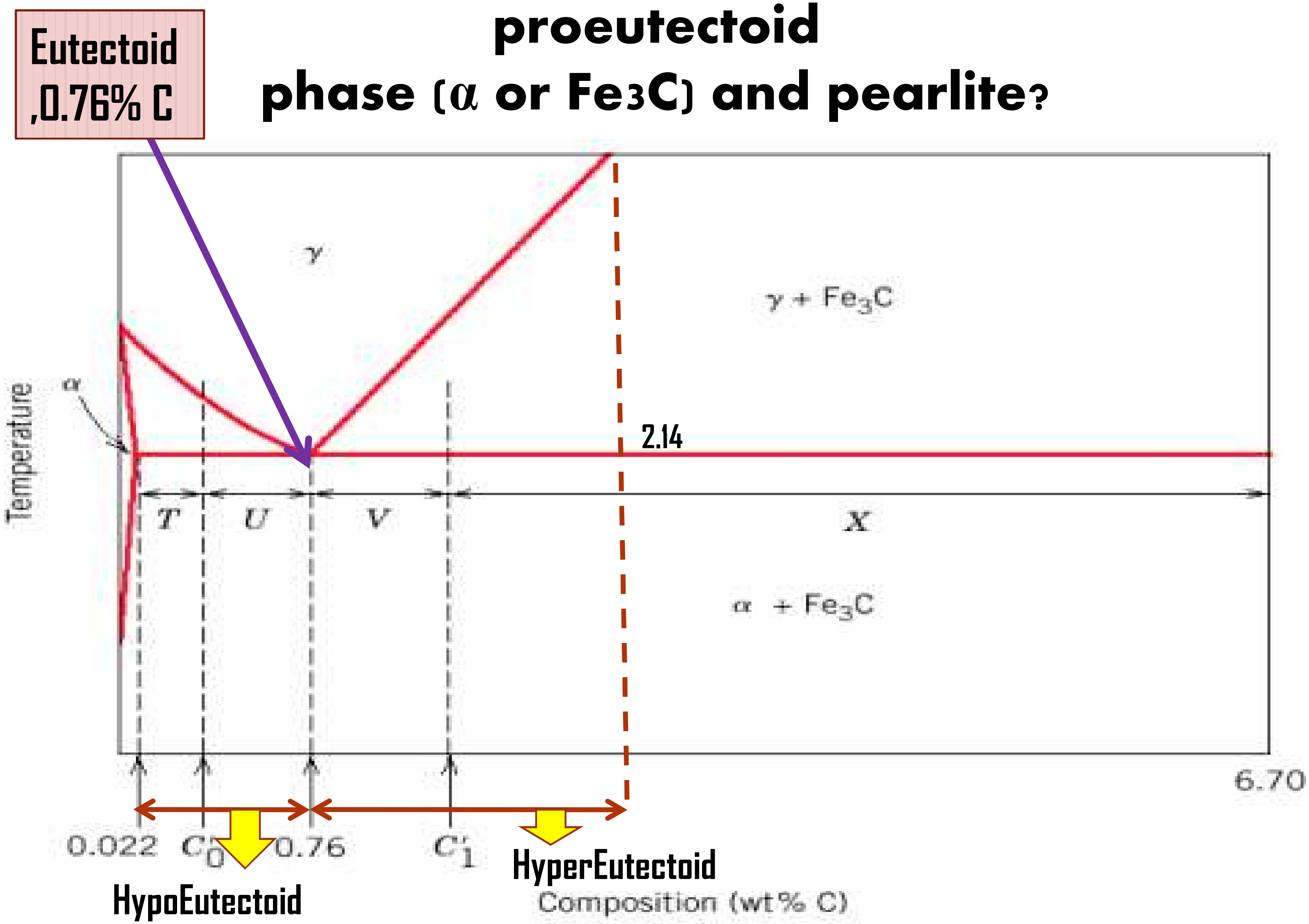
"Proeutectoid" means it formed ABOVE or BEFORE the Eutectoid Temperature!





1000
900
800
700
600
500
400
Temperature (°C)
γ
γ + Fe₃C
M
N
O
Tₑ
y
y'
c
d
e
f
α
Pearlite
Fe₃C
Proeutectoid α
Eutectoid α
α + Fe₃C
0
1.0
2.0
C₀
Composition (wt % C)

How to calculate the relative amounts of proeutectoid phase (α or Fe_3C) and pearlite?

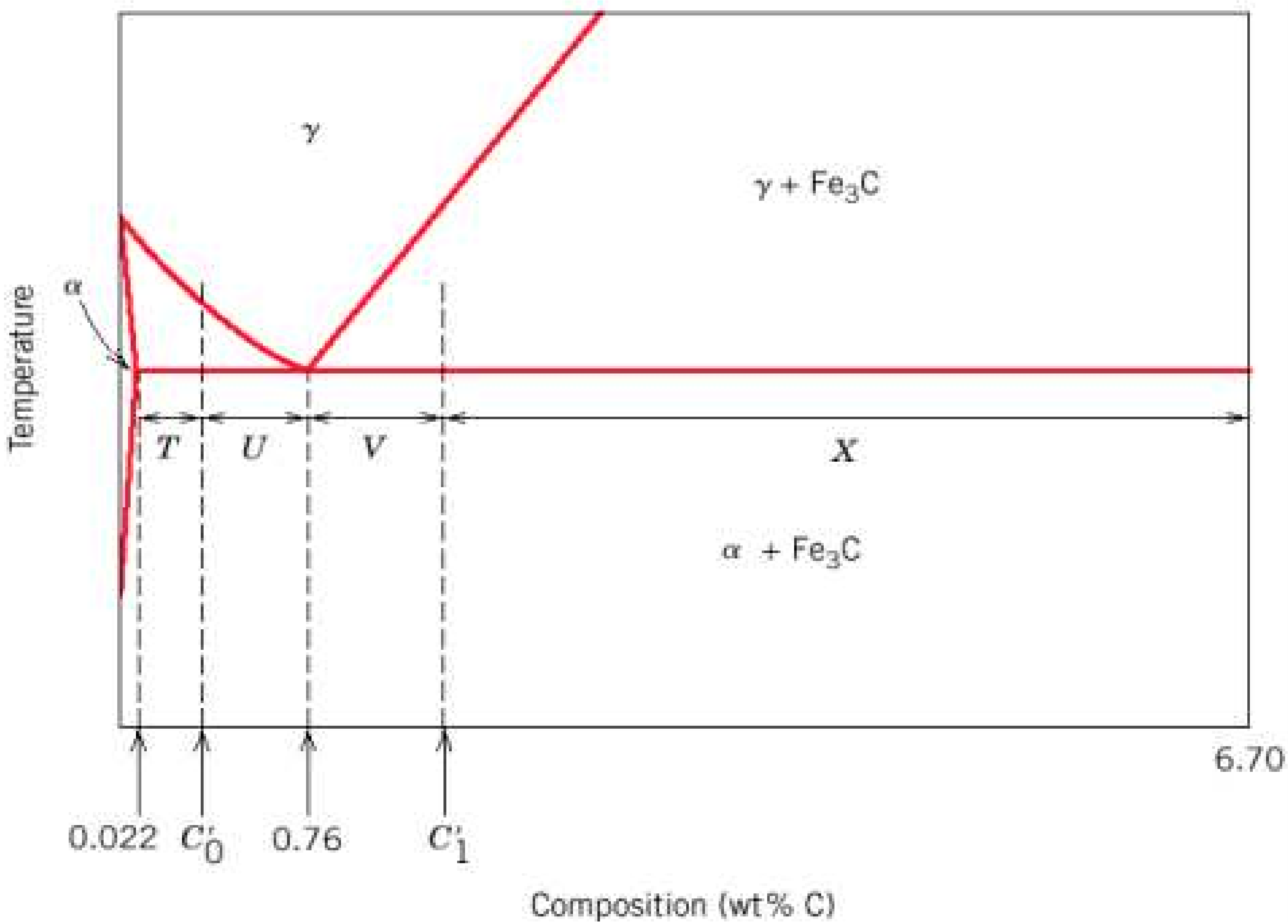


- **Fraction of pearlite:**

$$W_p = \frac{T}{T+U} = \frac{Co' - 0.022}{0.76 - 0.022} = \frac{Co' - 0.022}{0.74}$$

- **Fraction of Proeutectoid :**

$$W_{\alpha} = \frac{U}{T+U} = \frac{0.76 - Co'}{0.76 - 0.022} = \frac{0.76 - Co'}{0.74}$$


γ
γ + Fe3C
α
Temperature
T
U
V
X
α + Fe3C
6.70
0.022
C'0
0.76
C'1
Composition (wt% C)

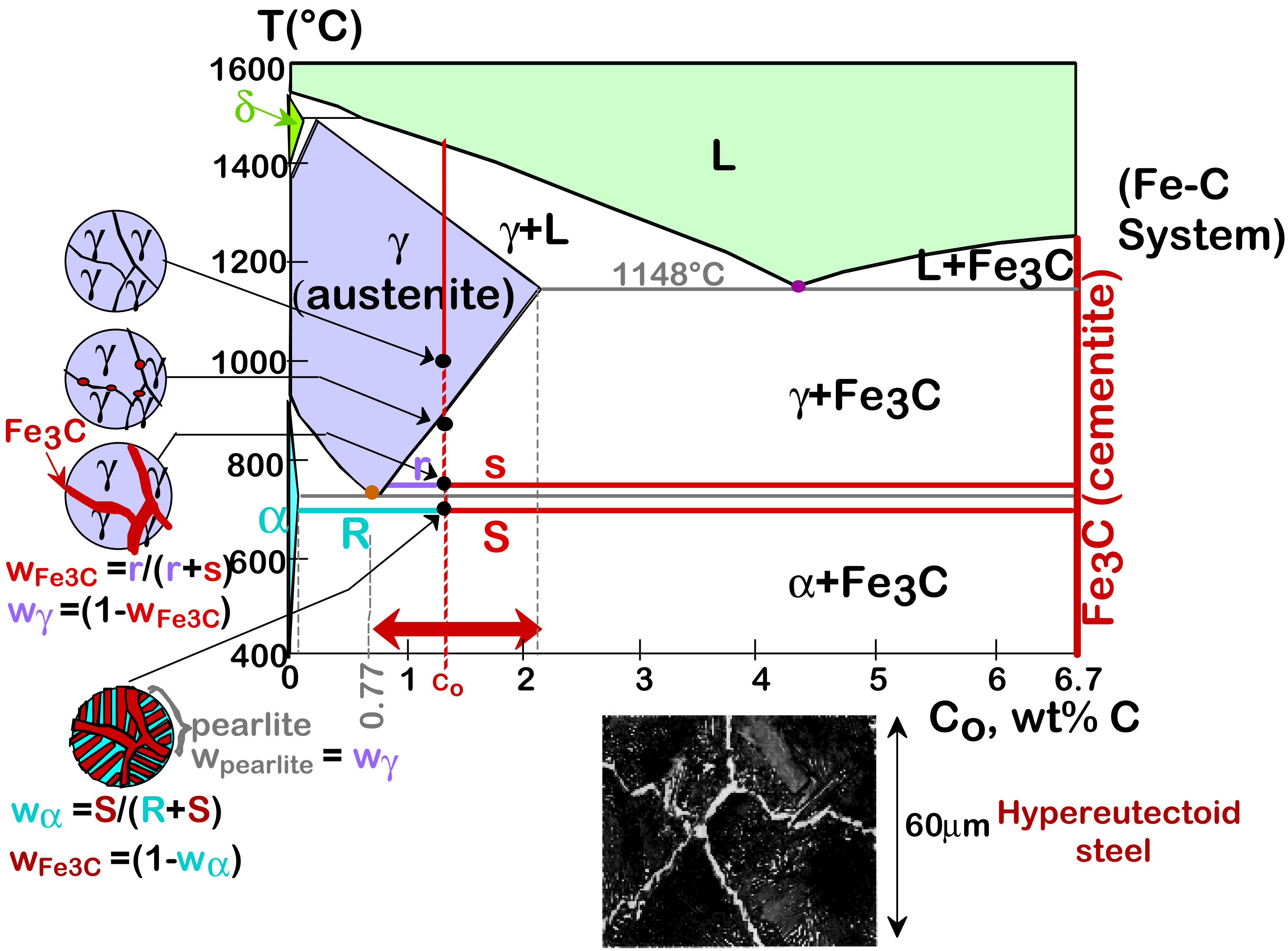
- **Fraction of pearlite: (for Hypereutectoid alloys)**

$$W_p = \frac{X}{V + X} = \frac{6.70 - C1'}{6.70 - 0.76} = \frac{6.70 - C1'}{5.94}$$

- **Fraction proeutectoid cementite: (Hypereutectoid)**

$$W_{Fe3C} = \frac{V}{V+X} = \frac{C1' - 0.76}{6.70 - 0.76} = \frac{C1' - 0.76}{5.94}$$

HYPEREUTECTOID STEEL



HYPER-EUTECTOID

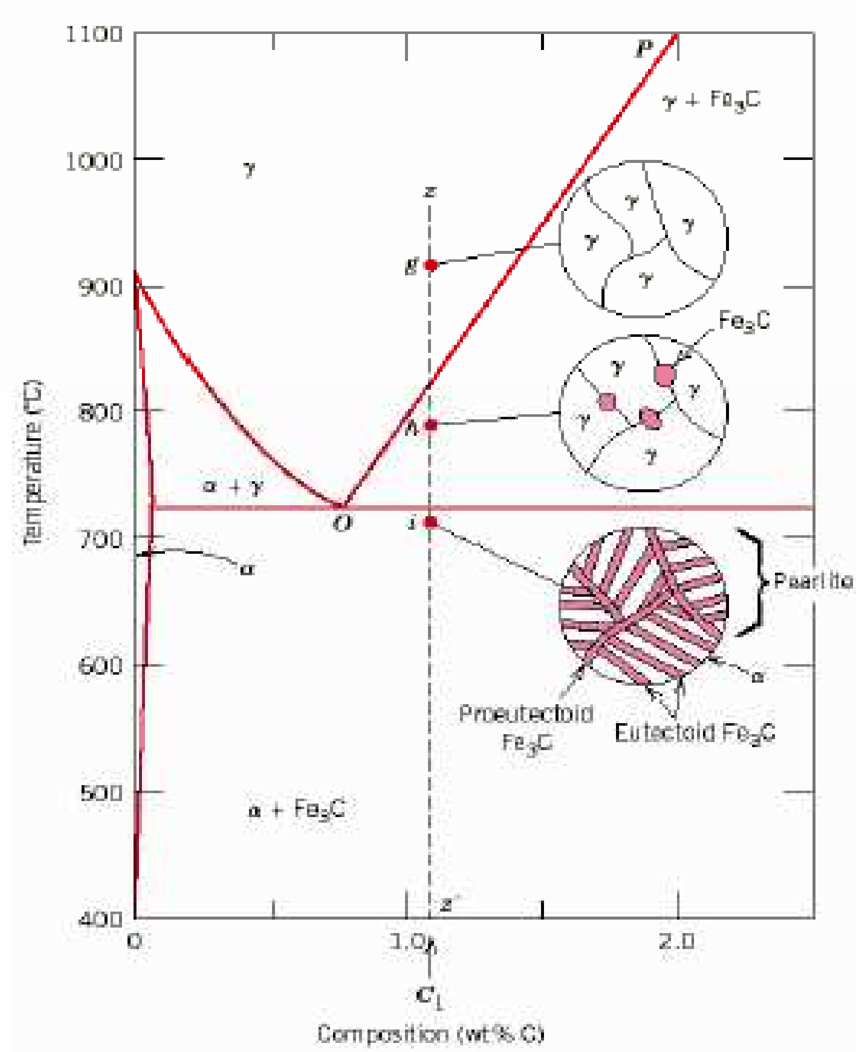
Hyper-eutectoid Composition (wt% C >0.76)

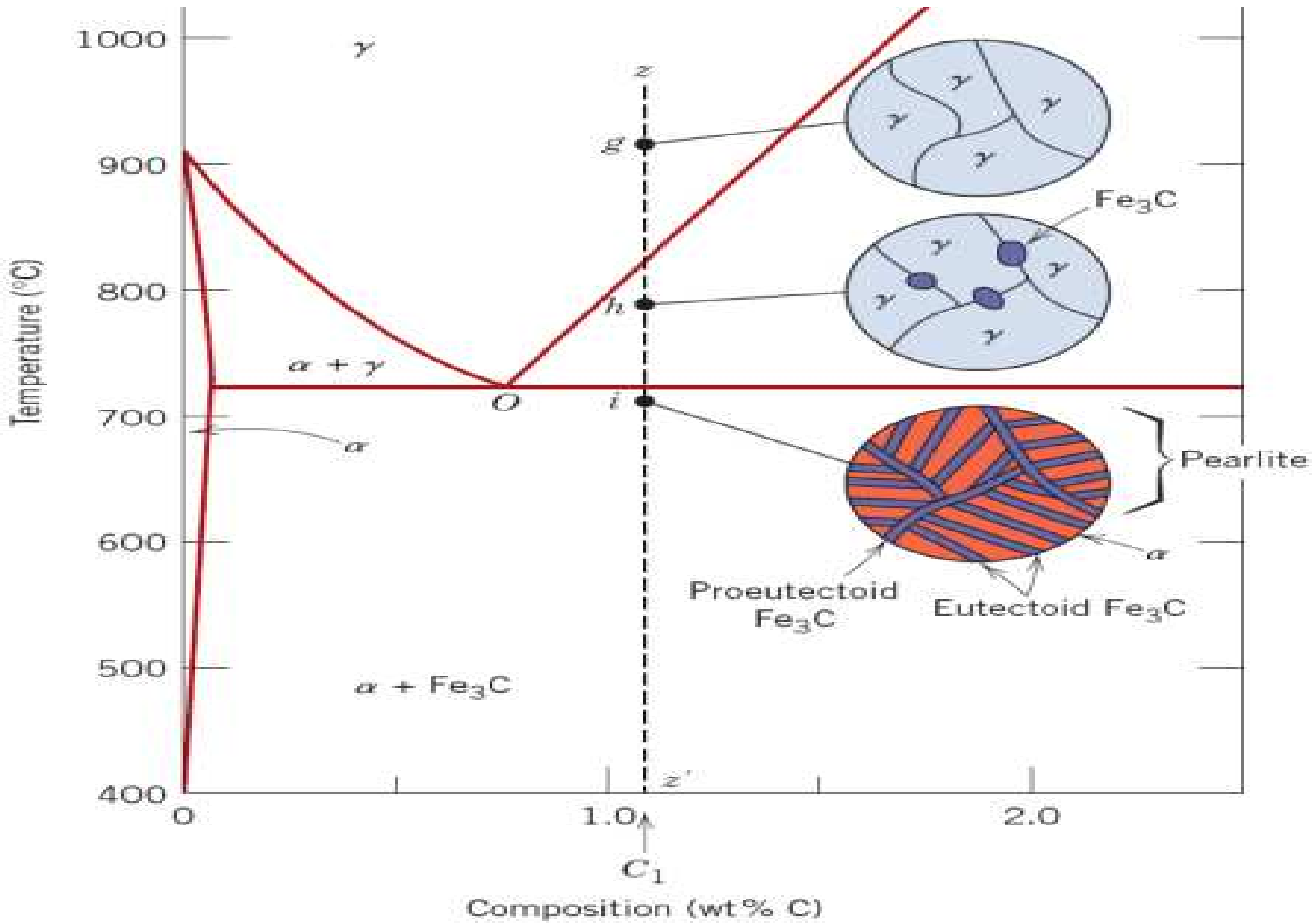
- Composition between 0.76 and 2.14 wt% C
- Upon cooling enter a two-phase region

$$\gamma \Rightarrow \gamma + Fe_3C$$

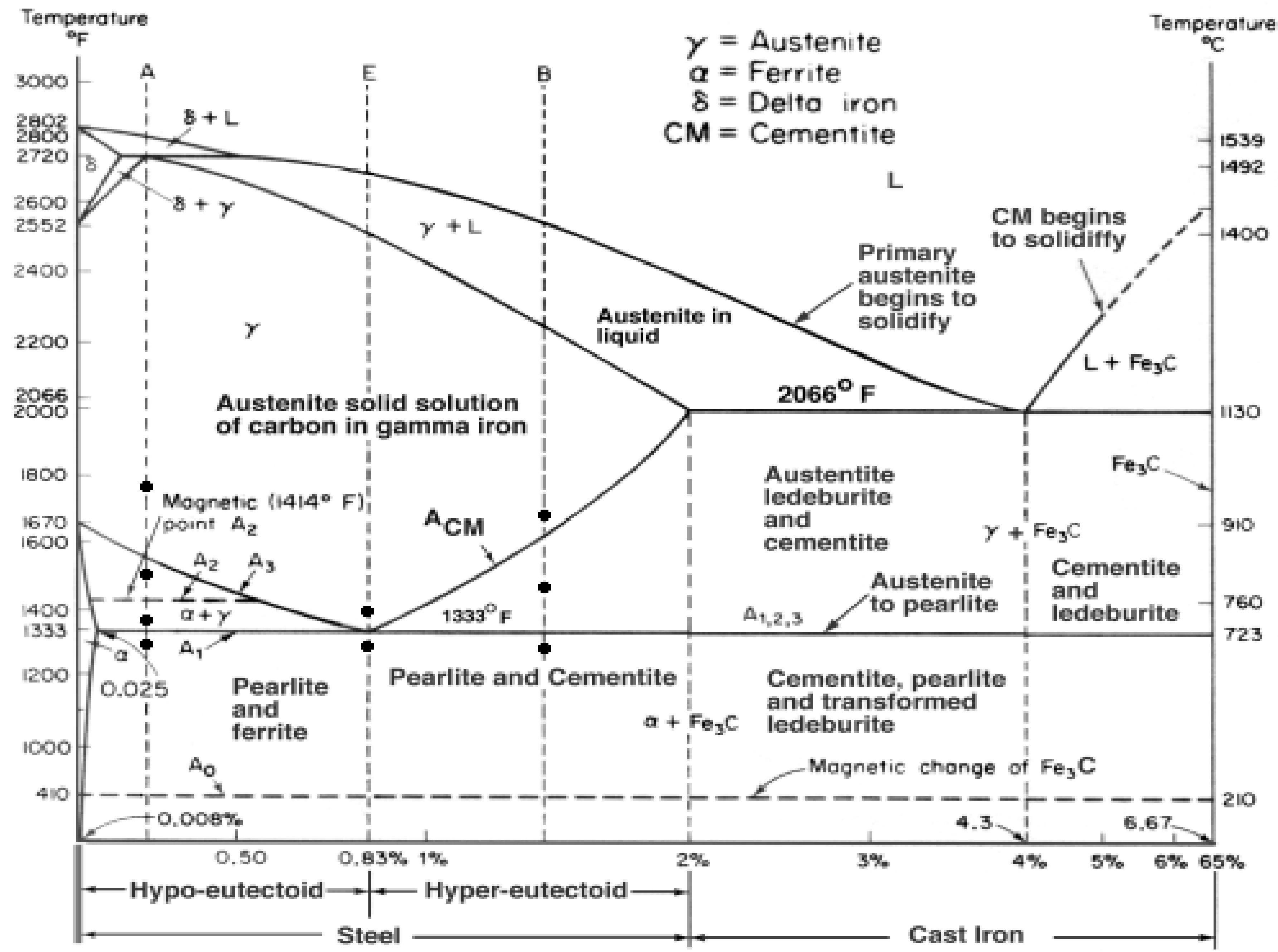
- The pro-eutectoid cementite phase has begun to form along the γ grain boundaries

"Proeutectoid" means it formed ABOVE or BEFORE the Eutectoid Temperature!





1000
900
800
700
600
500
400
Temperature (°C)
γ
α + γ
α
O
α + Fe3C
z
g
h
i
z'
0
1.0
2.0
C1
Composition (wt% C)
Fe3C
Pearlite
Proeutectoid Fe3C
Eutectoid Fe3C



Temperature °F
Temperature °C
γ = Austenite
α = Ferrite
δ = Delta iron
CM = Cementite
A
E
B
3000
2802
2800
2720
2600
2552
2400
2200
2066
2000
1800
1670
1600
1400
1333
1200
1000
410
1539
1492
1400
1130
910
760
723
210
δ + L
δ
δ + γ
γ + L
L
γ
CM begins to solidiffy
Primary austenite begins to solidify
Austenite in liquid
L + Fe3C
2066° F
Austenite solid solution of carbon in gamma iron
Austentite ledeburite and cementite
Fe3C
Magnetic (1414° F) point A2
ACM
γ + Fe3C
A2
A3
Cementite and ledeburite
Austenite to pearlite
α + γ
1333° F
A1,2,3
A1
α
0.025
Pearlite and ferrite
Pearlite and Cementite
Cementite, pearlite and transformed ledeburite
α + Fe3C
A0
Magnetic change of Fe3C
0.008%
4.3
6.67
0.50
0.83%
1%
2%
3%
4%
5%
6%
65%
Hypo-eutectoid
Hyper-eutectoid
Steel
Cast Iron

THANK YOU