Universidad de Chile
Facultad de Ciencias Físicas y Matemáticas
Departamento de Ingeniería Mecánica

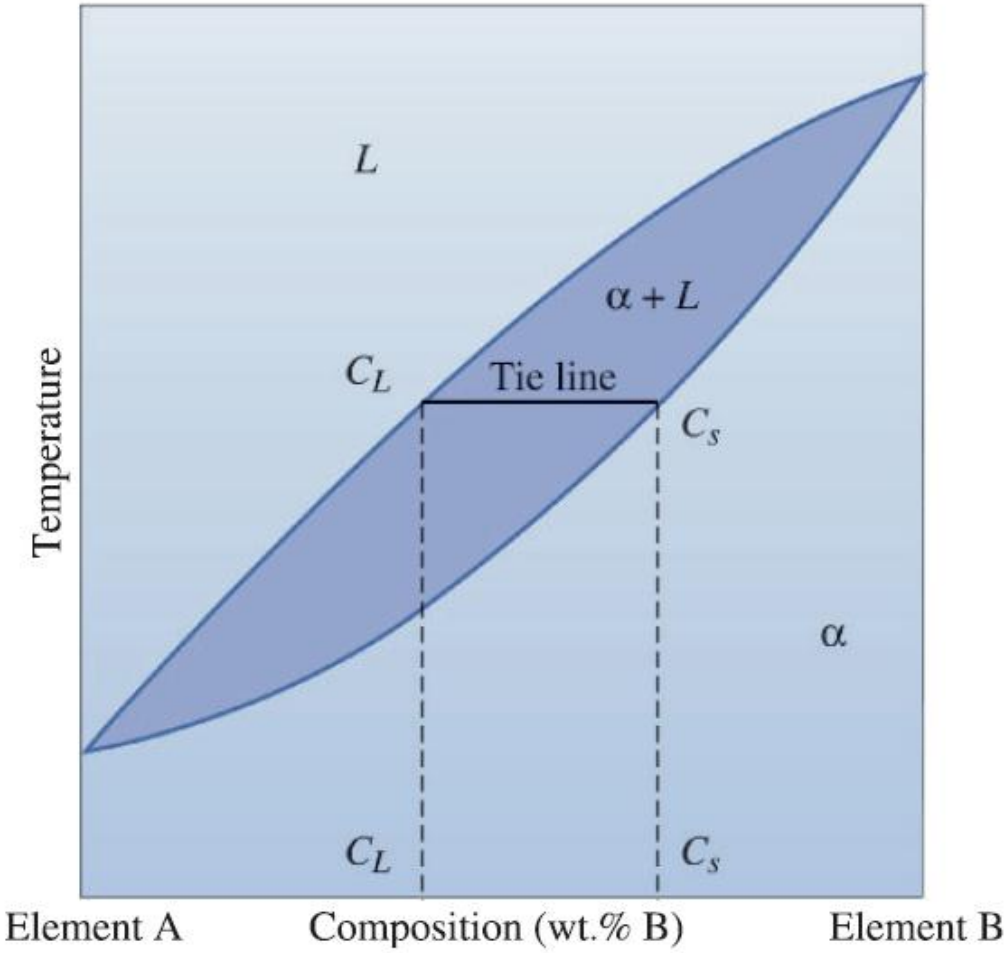
Diagramas de Fase

ME4601 – Ingeniería de Materiales II

Nombre: Rodrigo Bahamondes S.
Prof. Cátedra: Ali Akbari F.

16 de Octubre de 2015

Solidificación de Aleaciones



Solidificación de Aleaciones

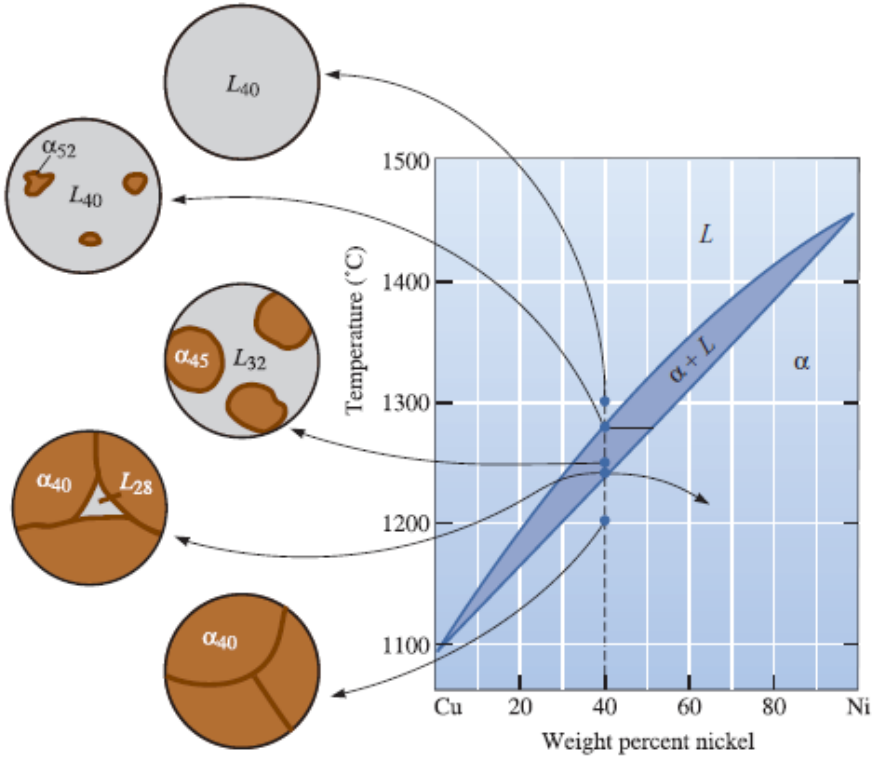


Figure 10-15 The change in structure of a Cu-40% Ni alloy during equilibrium solidification. The nickel and copper atoms must diffuse during cooling in order to satisfy the phase diagram and produce a uniform equilibrium structure.

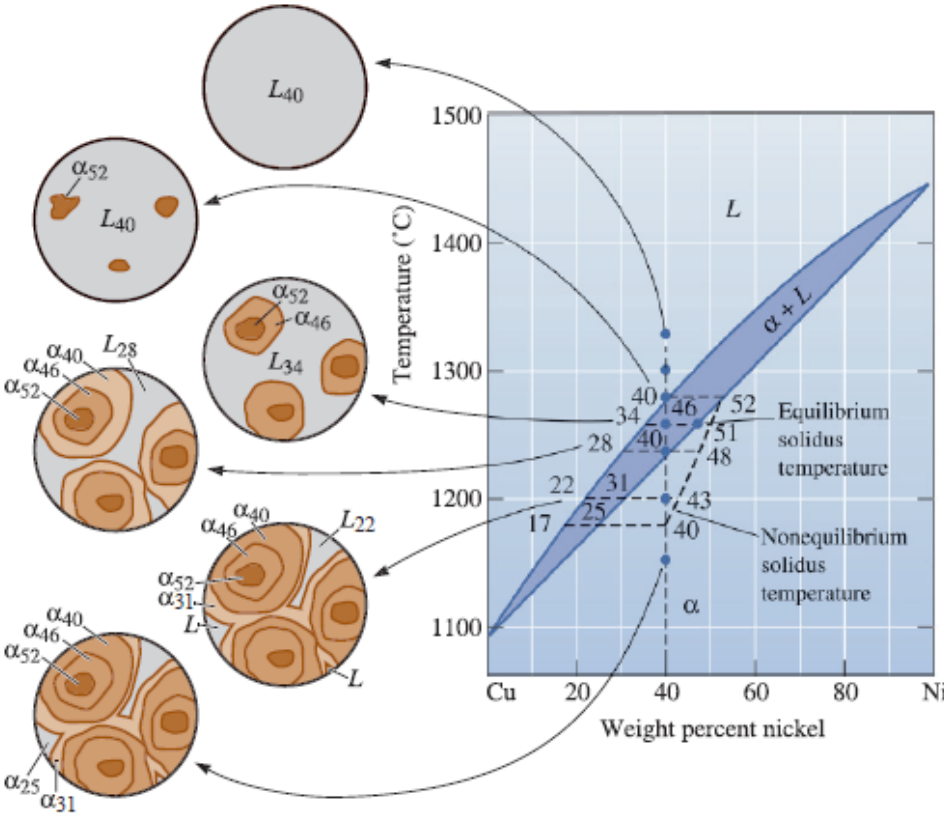


Figure 10-17 The change in structure of a Cu-40% Ni alloy during nonequilibrium solidification. Insufficient time for diffusion in the solid produces a segregated structure. Notice the nonequilibrium solidus curve.

Reacción Eutéctica

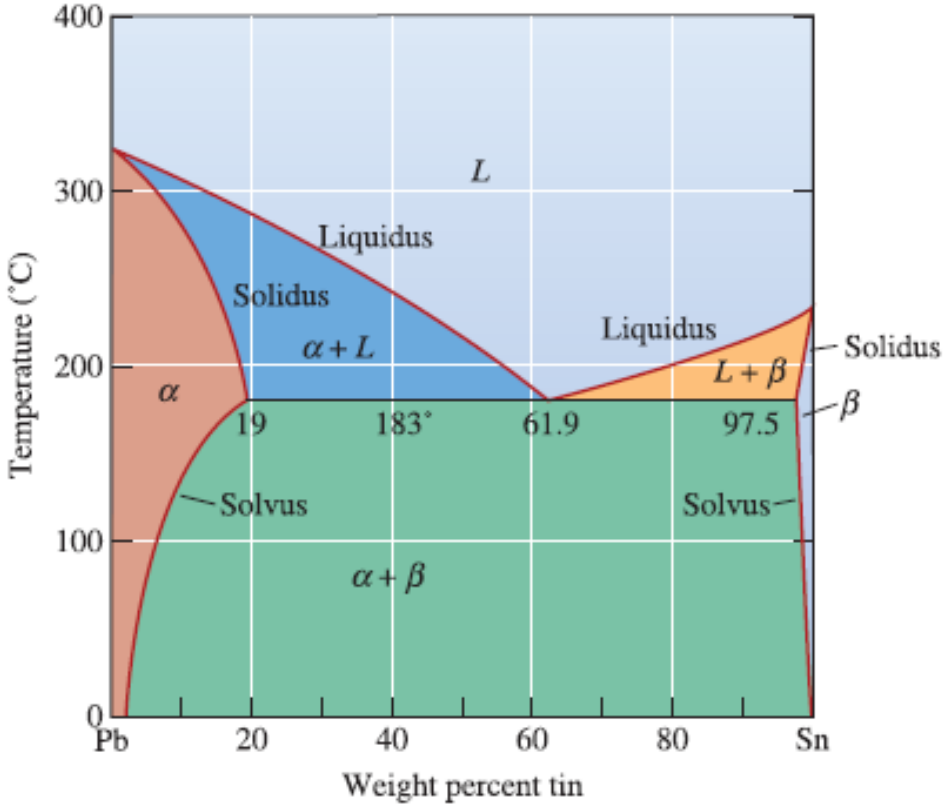


Figure 11-6 The lead–tin equilibrium phase diagram.

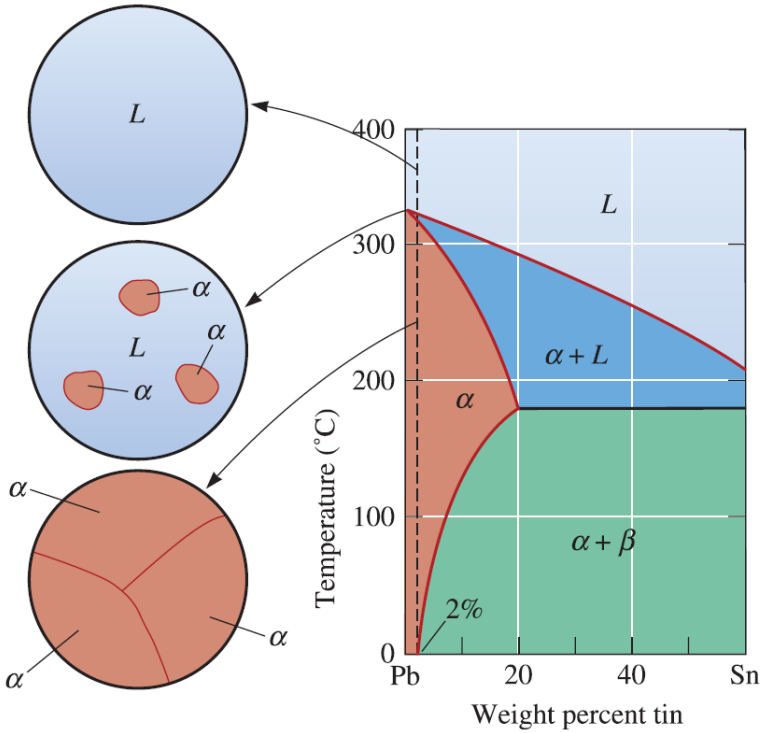


Figure 11-7 Solidification and microstructure of a Pb-2% Sn alloy. The alloy is a single-phase solid solution.

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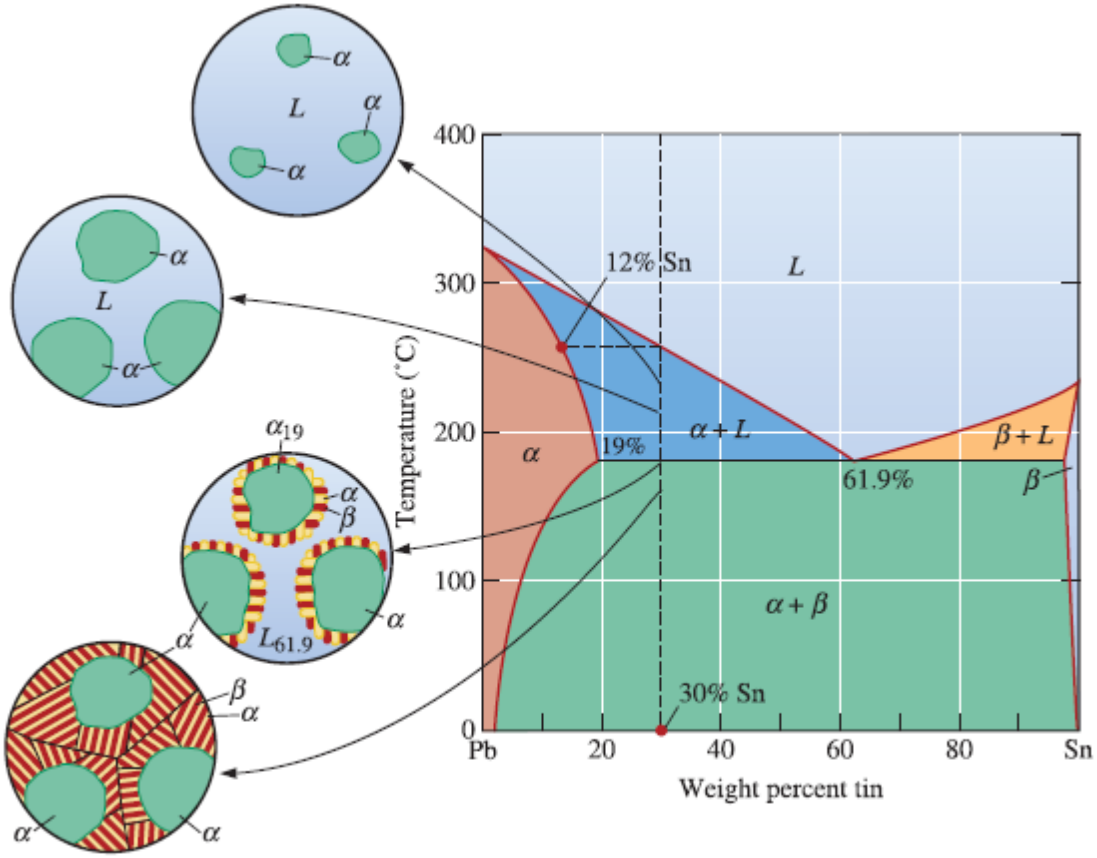


Figure 11-13 The solidification and microstructure of a hypoeutectic alloy (Pb-30% Sn).

Reacción Eutéctica

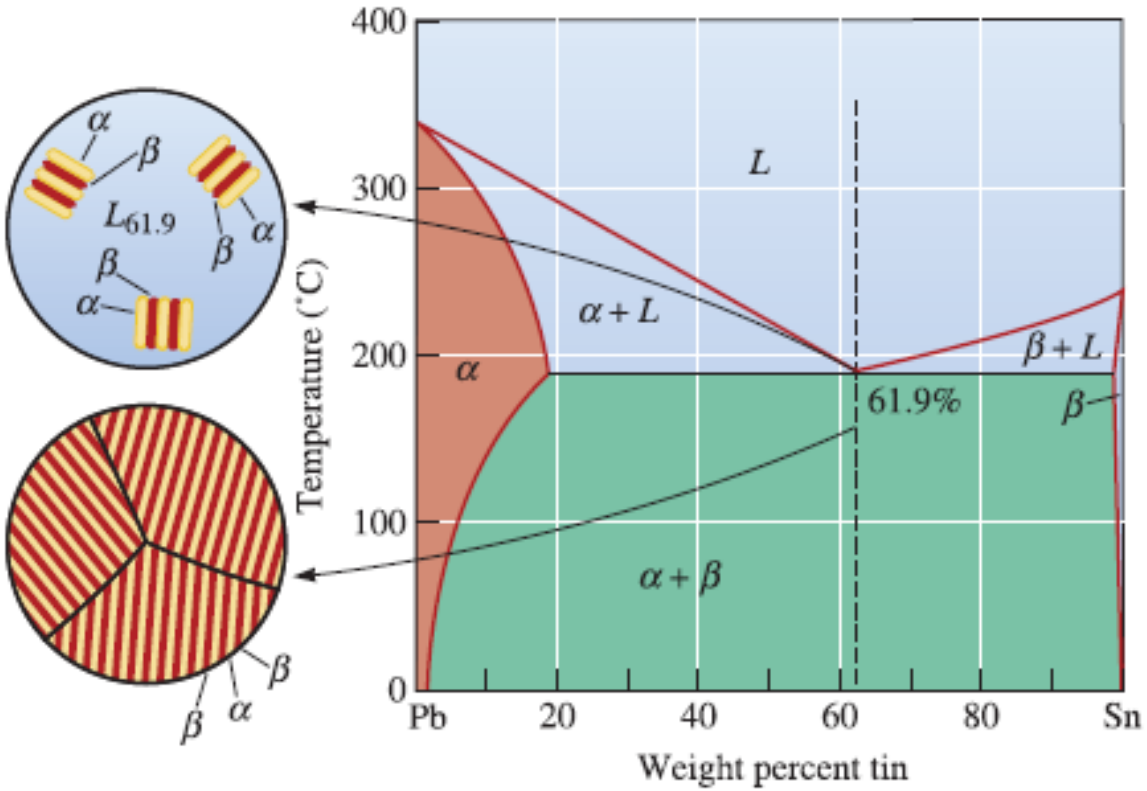


Figure 11-9 Solidification and microstructure of the eutectic alloy Pb-61.9% Sn.

Otras reacciones

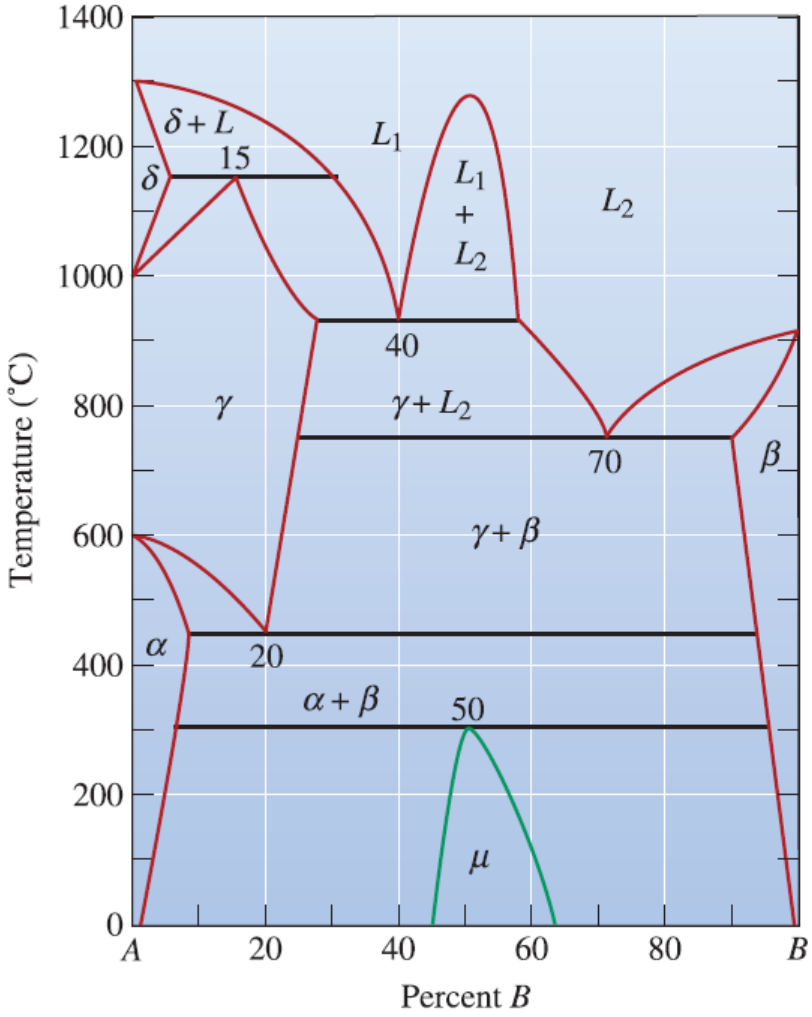


Figure 11-5
A hypothetical phase diagram (for Example 11-1).

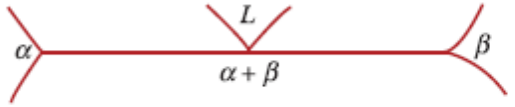
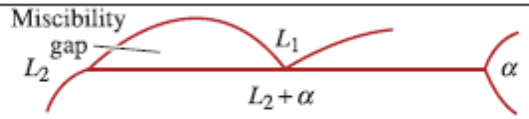
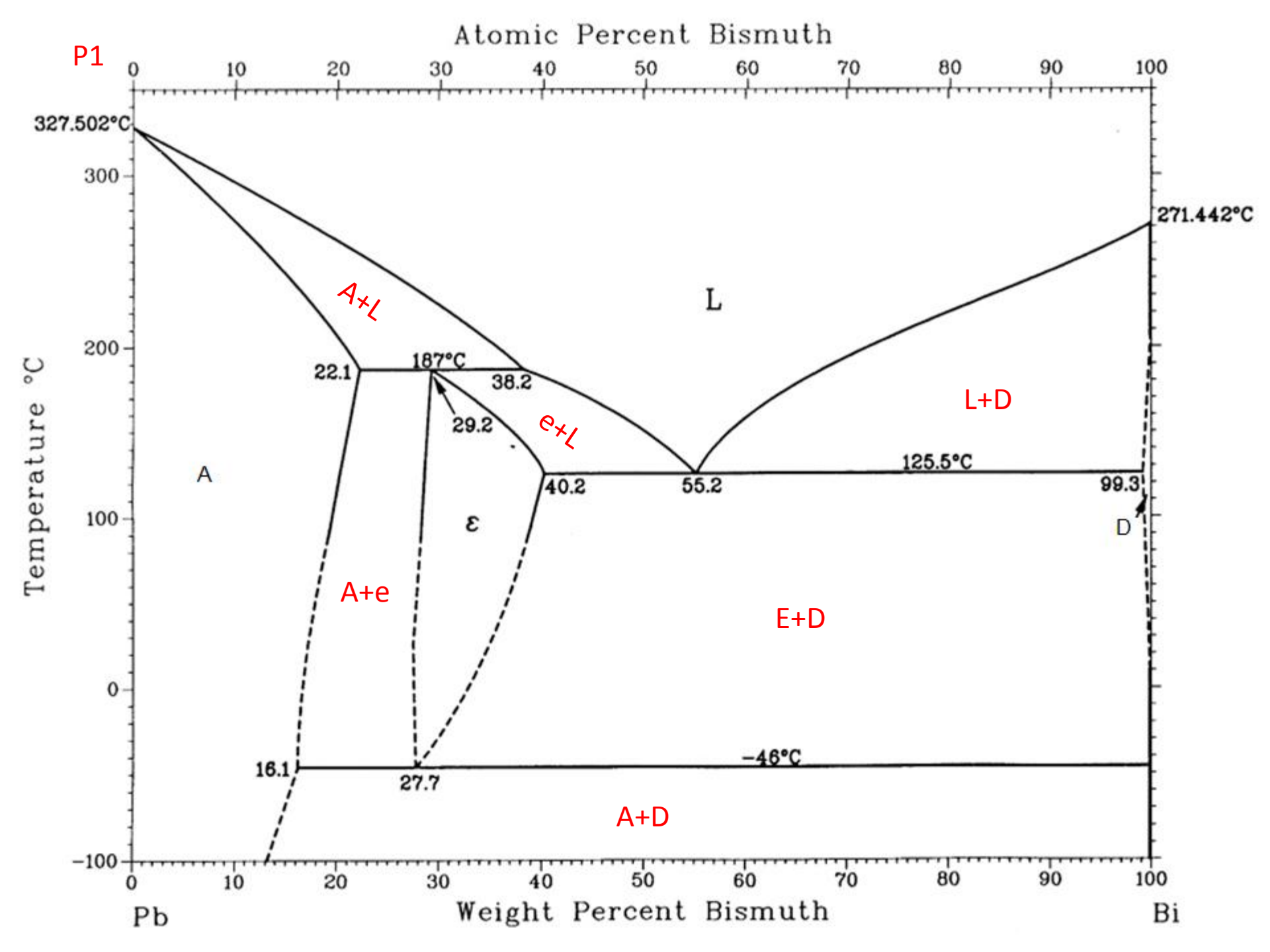
Eutectic	$L \rightarrow \alpha + \beta$	
Peritectic	$\alpha + L \rightarrow \beta$	
Monotectic	$L_1 \rightarrow L_2 + \alpha$	
Eutectoid	$\gamma \rightarrow \alpha + \beta$	
Peritectoid	$\alpha + \beta \rightarrow \gamma$	

Figure 11-4 The five most important three-phase reactions in binary phase diagrams.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Atomic Percent Bismuth
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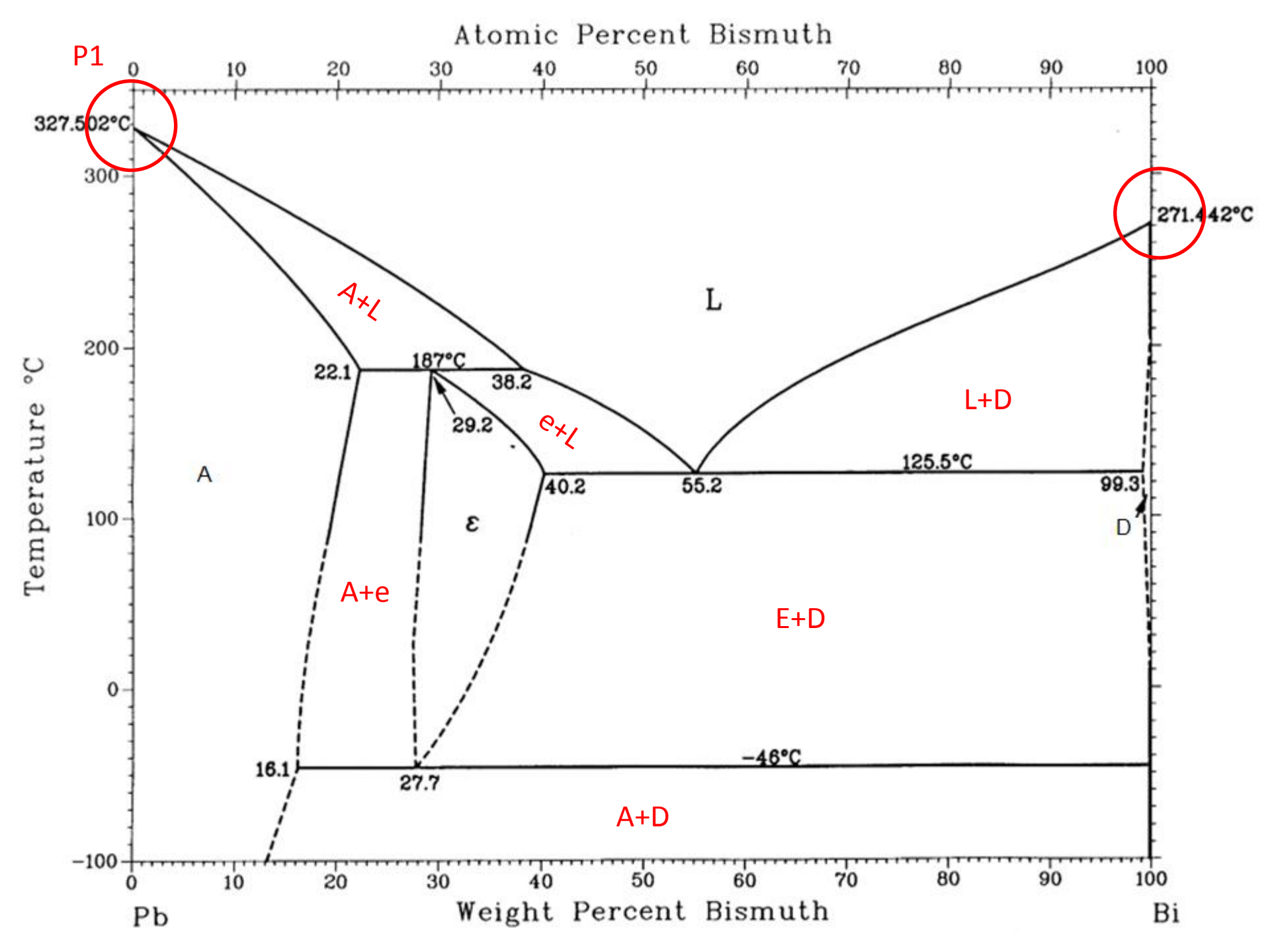
10
20
30
40
50
60
70
80
90
100
327.502°C
300
200
100
0
−100
271.442°C
Temperature °C
A+L
L
L+D
e+L
A
ε
A+e
E+D
A+D
22.1
187°C
38.2
29.2
40.2
55.2
125.5°C
99.3
D
16.1
27.7
−46°C
Pb
Weight Percent Bismuth
Bi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Atomic Percent Bismuth
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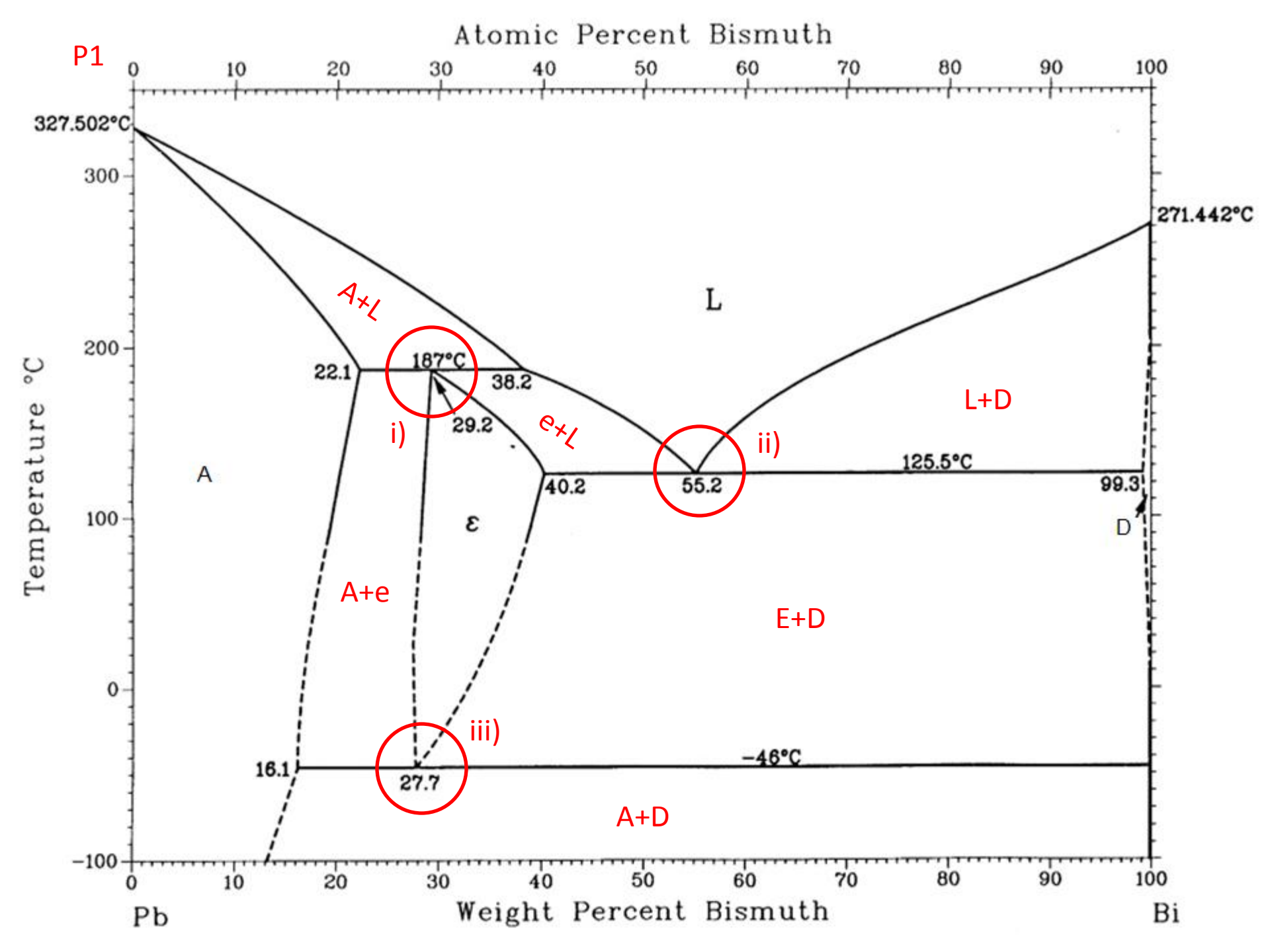
10
20
30
40
50
60
70
80
90
100
327.502°C
271.442°C
300
200
100
0
−100
Temperature °C
A+L
L
L+D
22.1
187°C
38.2
29.2
e+L
A
ε
125.5°C
40.2
55.2
99.3
D
A+e
E+D
16.1
27.7
−46°C
A+D
Pb
Weight Percent Bismuth
Bi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Atomic Percent Bismuth
0
10
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30
40
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60
70
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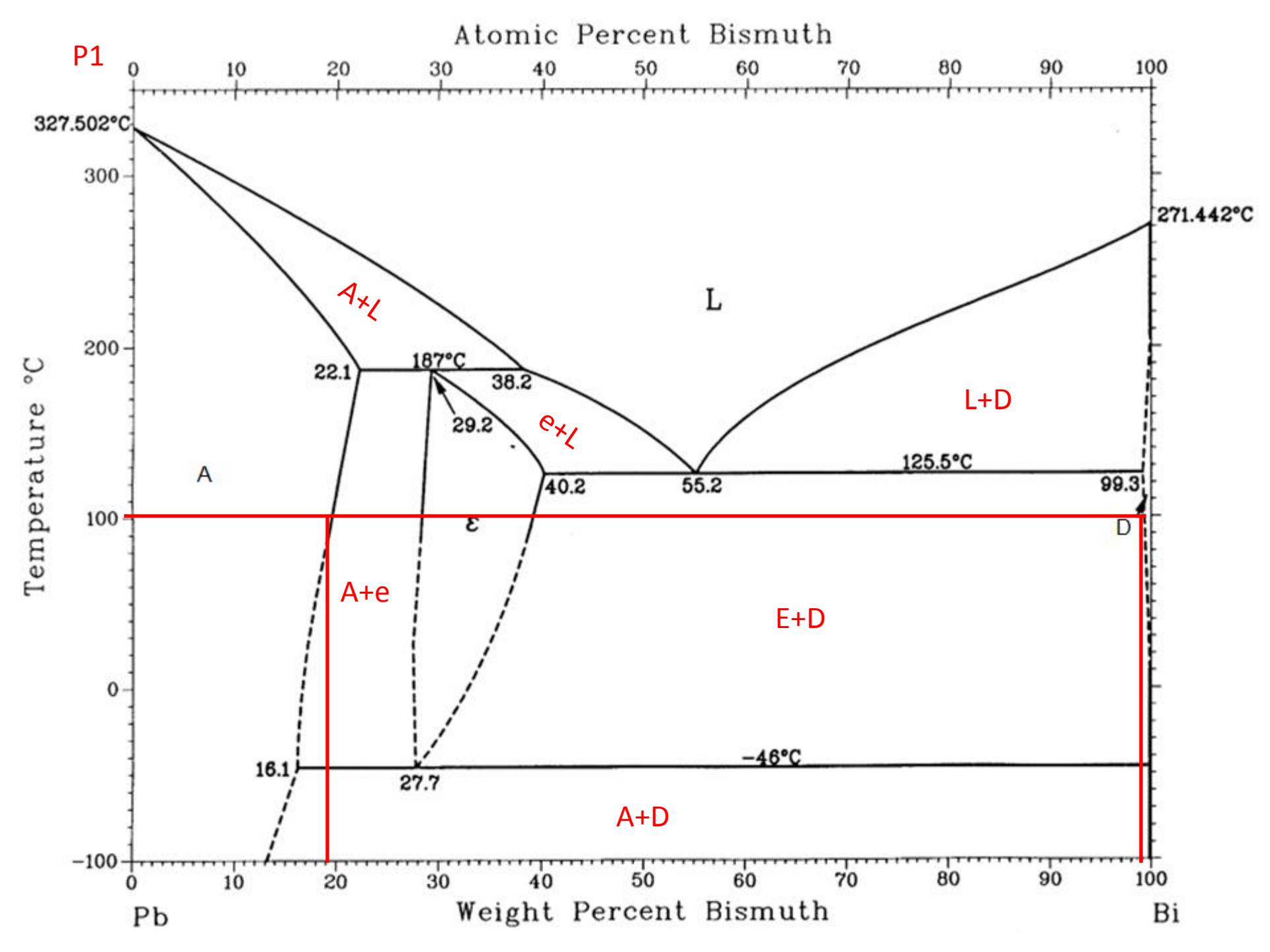
90
100
327.502°C
300
200
100
0
−100
271.442°C
Temperature °C
A+L
L
22.1
187°C
38.2
29.2
i)
e+L
ii)
L+D
125.5°C
A
40.2
55.2
99.3
D
ε
A+e
E+D
iii)
16.1
27.7
−46°C
A+D
Pb
Weight Percent Bismuth
Bi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Atomic Percent Bismuth
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10
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40
50
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70
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90
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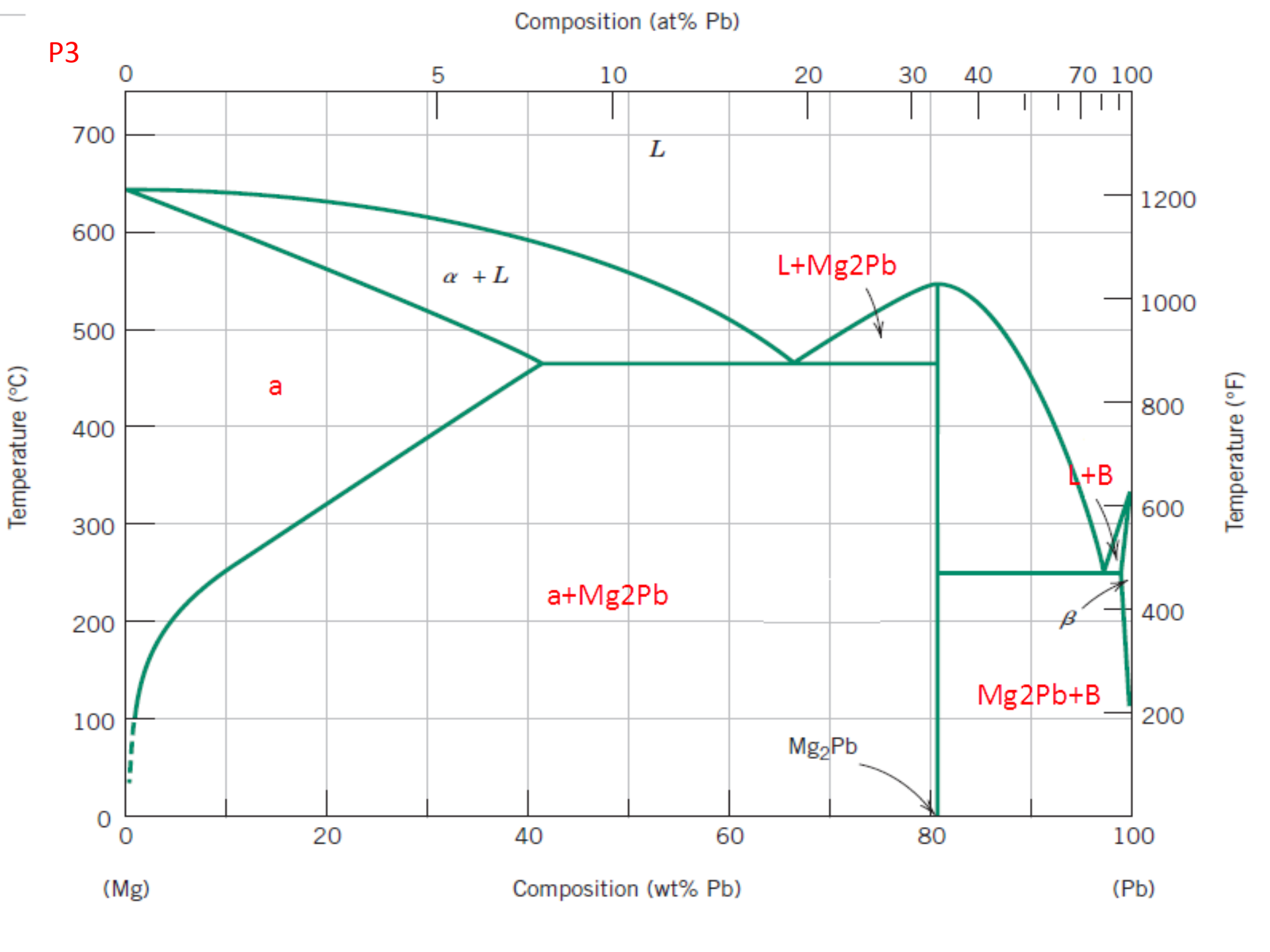
327.502°C
300
200
100
0
−100
271.442°C
Temperature °C
A+L
L
L+D
e+L
A
A+e
E+D
A+D
ε
22.1
187°C
38.2
29.2
40.2
55.2
125.5°C
99.3
D
16.1
27.7
−46°C
Pb
Weight Percent Bismuth
Bi

P3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10
20
30
40
70
100
700
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500
400
300
200
100
0
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α + L
a
L+Mg2Pb
L+B
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
600
400
200
Temperature (°C)
Temperature (°F)
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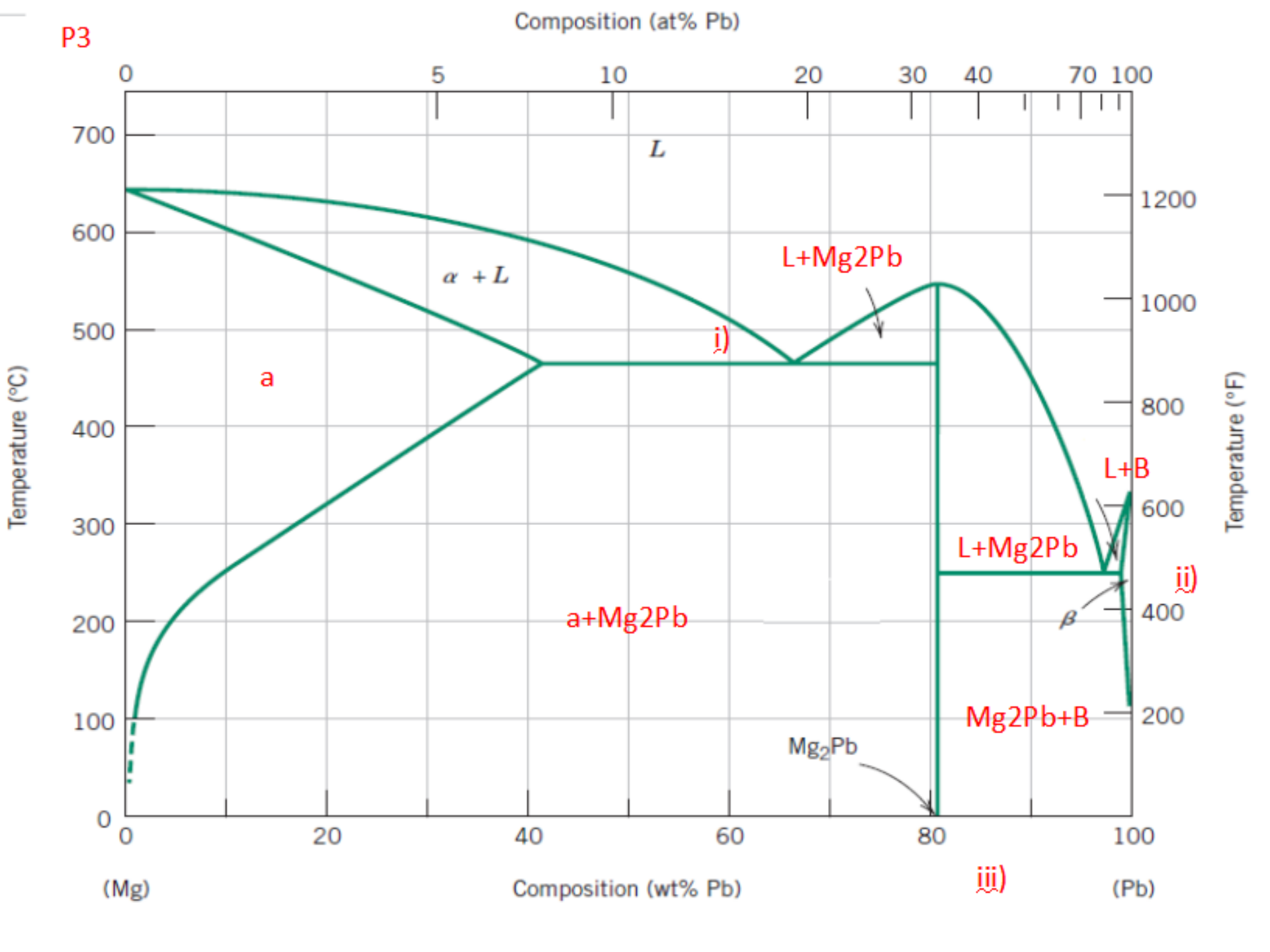
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P3


Composition (at% Pb)
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40
70
100
700
600
500
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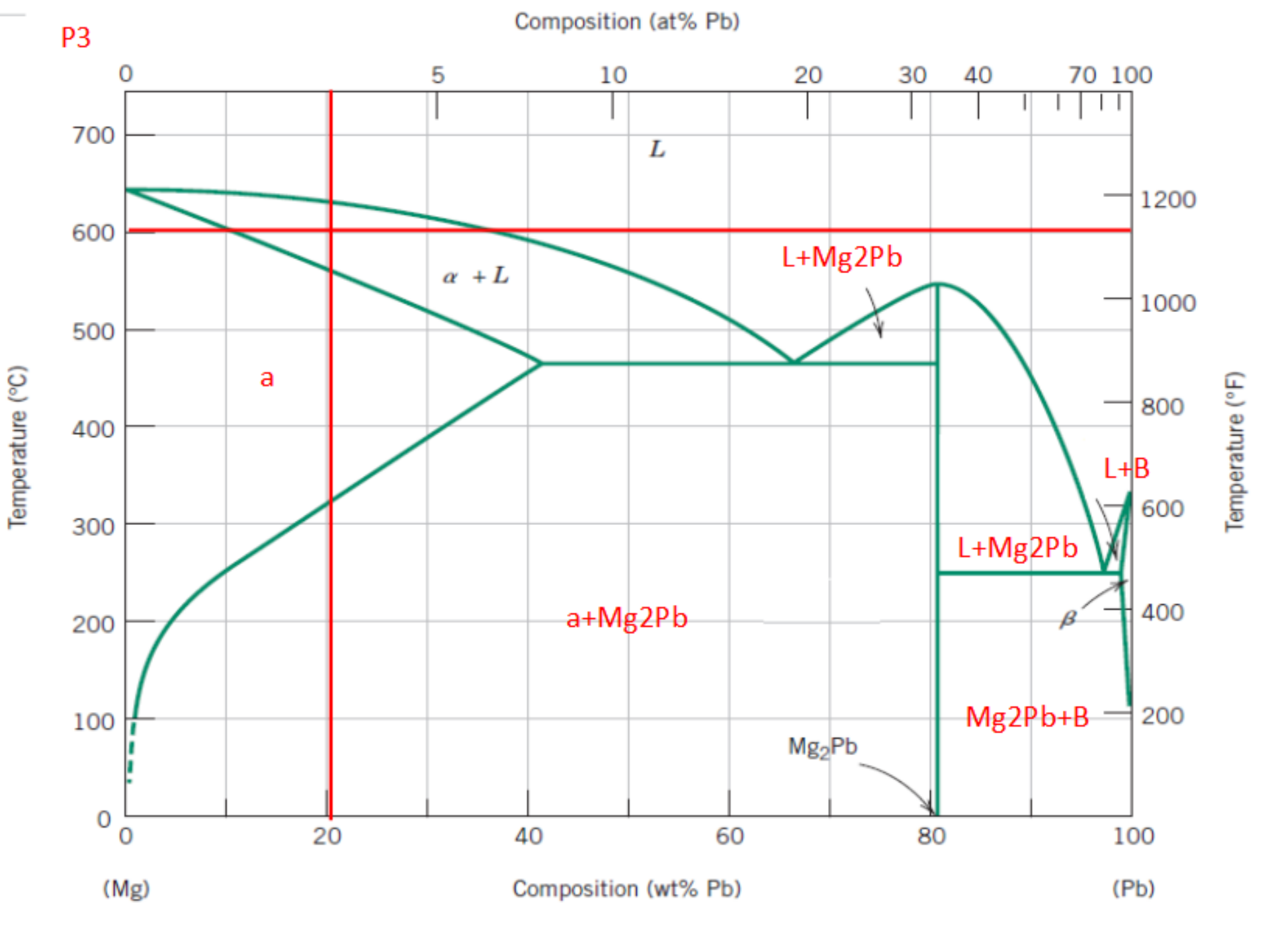
300
200
100
0
L
α + L
a
i)
L+Mg2Pb
L+B
L+Mg2Pb
ii)
β
a+Mg2Pb
Mg2Pb+B
Mg2Pb
iii)
Temperature (°C)
Temperature (°F)
1200
1000
800
600
400
200
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P3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α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
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Temperature (°C)
Temperature (°F)
0
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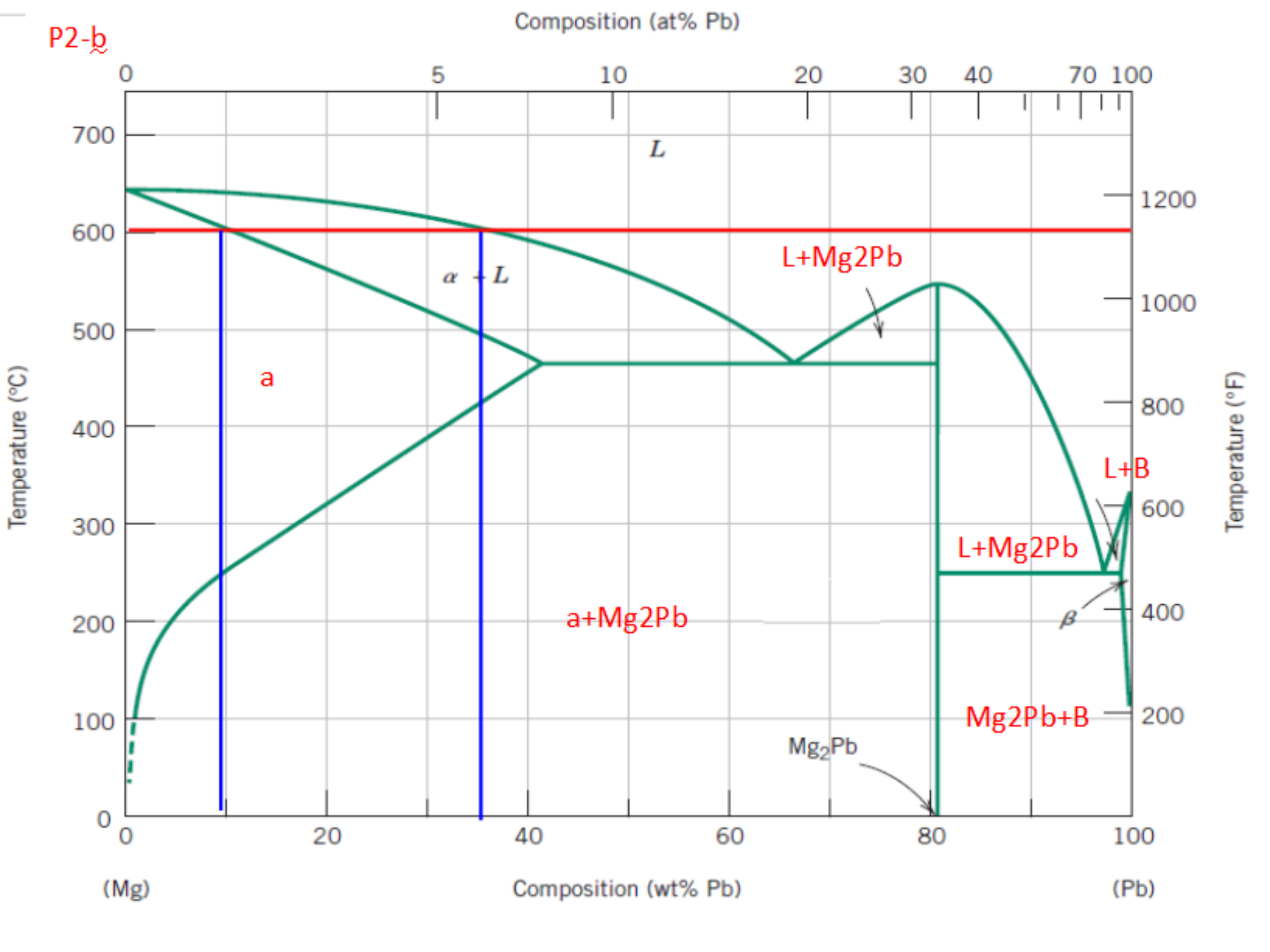
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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α + L
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L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
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Temperature (°C)
Temperature (°F)
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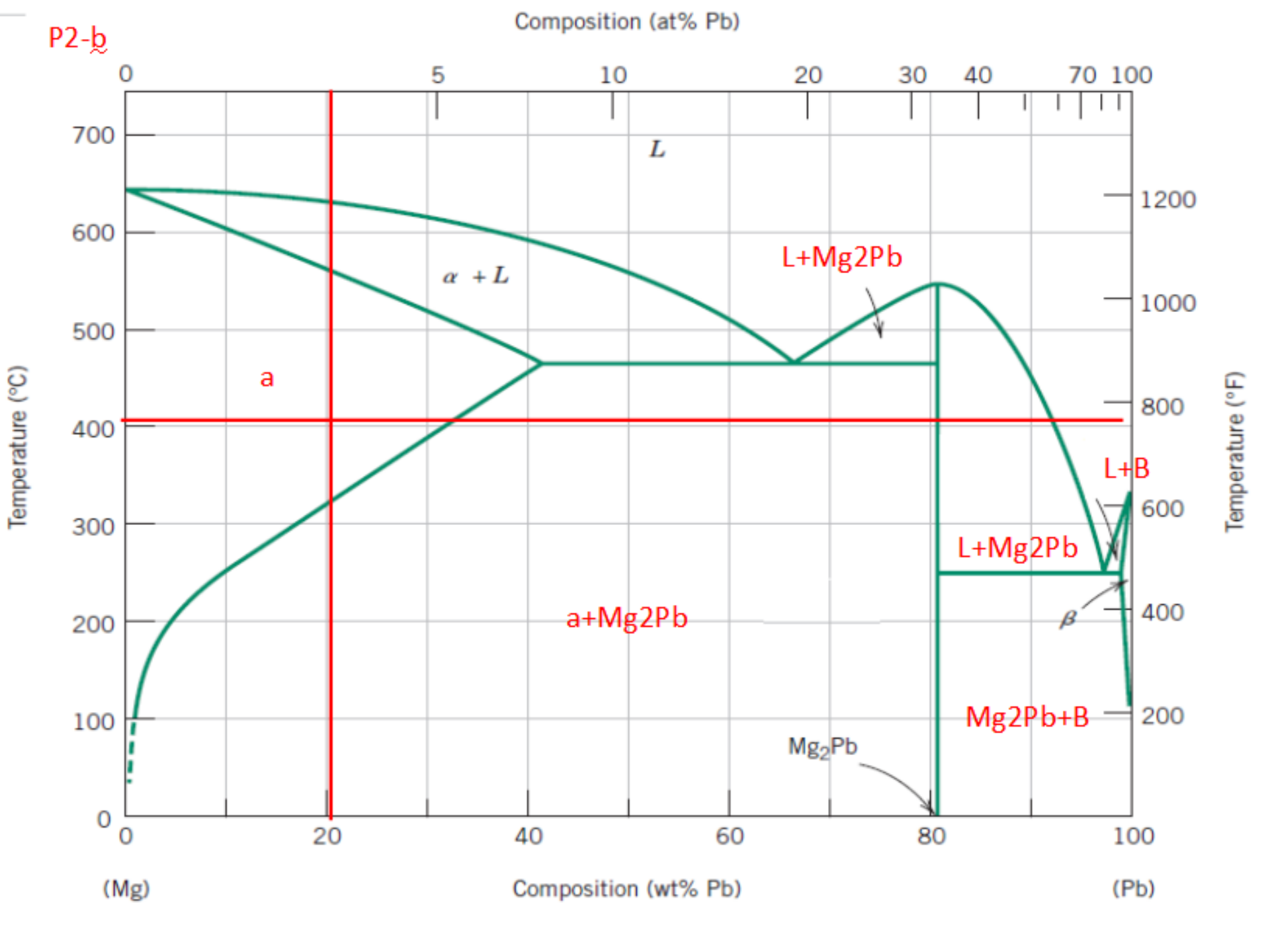
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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a+Mg2Pb
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Mg2Pb+B
Mg2Pb
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Temperature (°F)
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(Mg)
Composition (wt% Pb)
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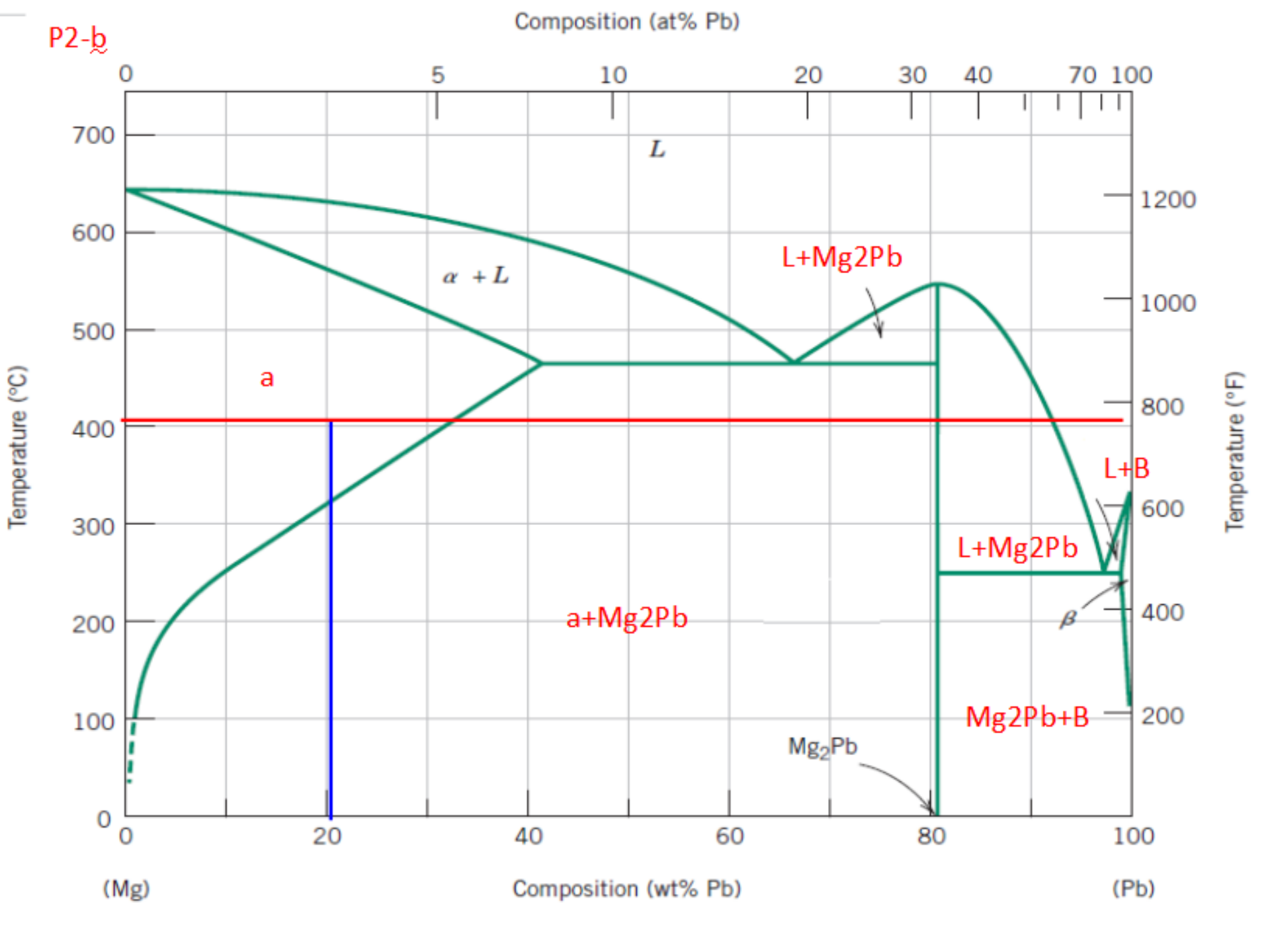
P2-b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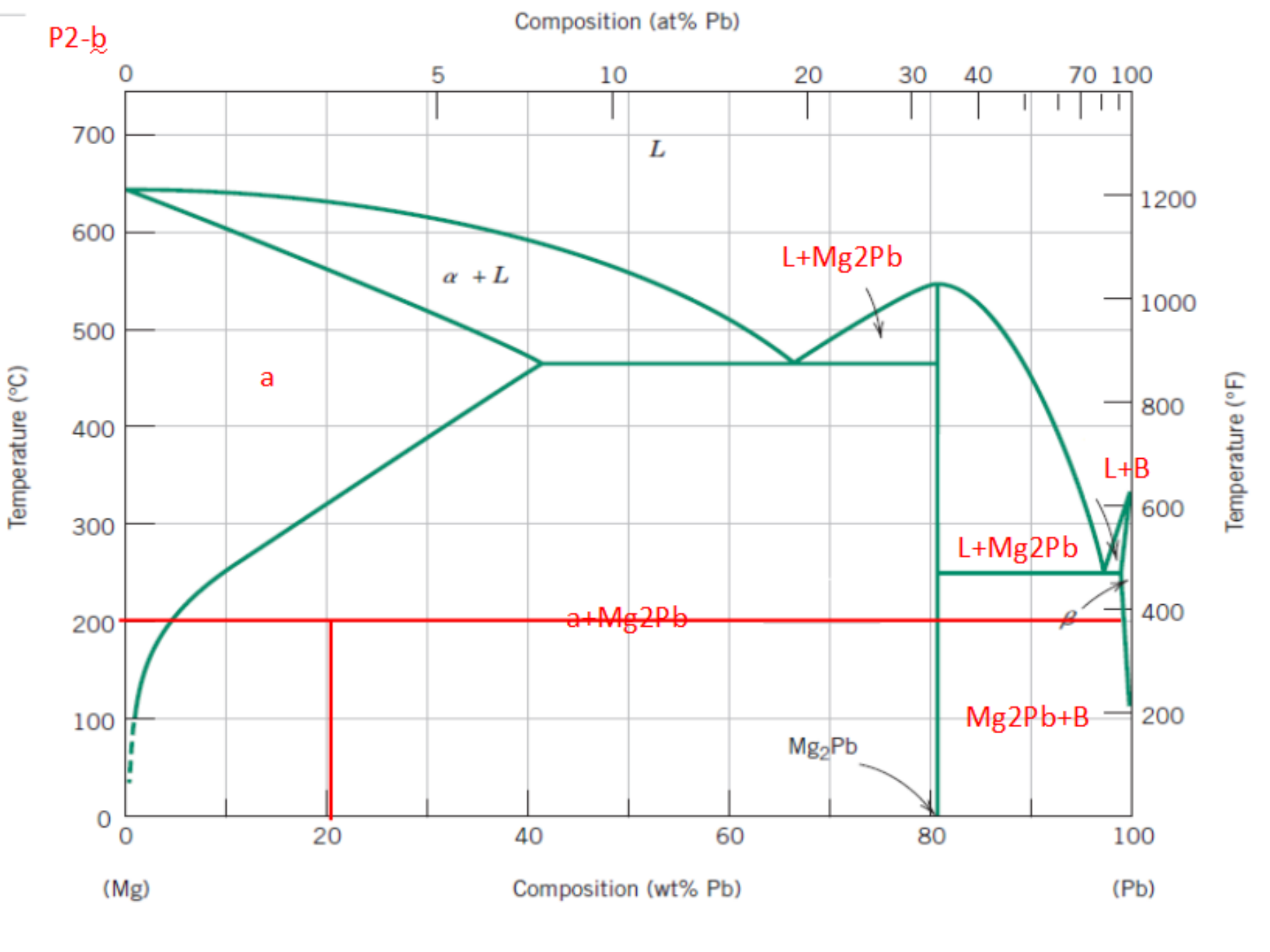
Composition (wt% Pb)
(Pb)

P2-b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L+Mg2Pb
a+Mg2Pb
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Mg2Pb
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Temperature (°F)
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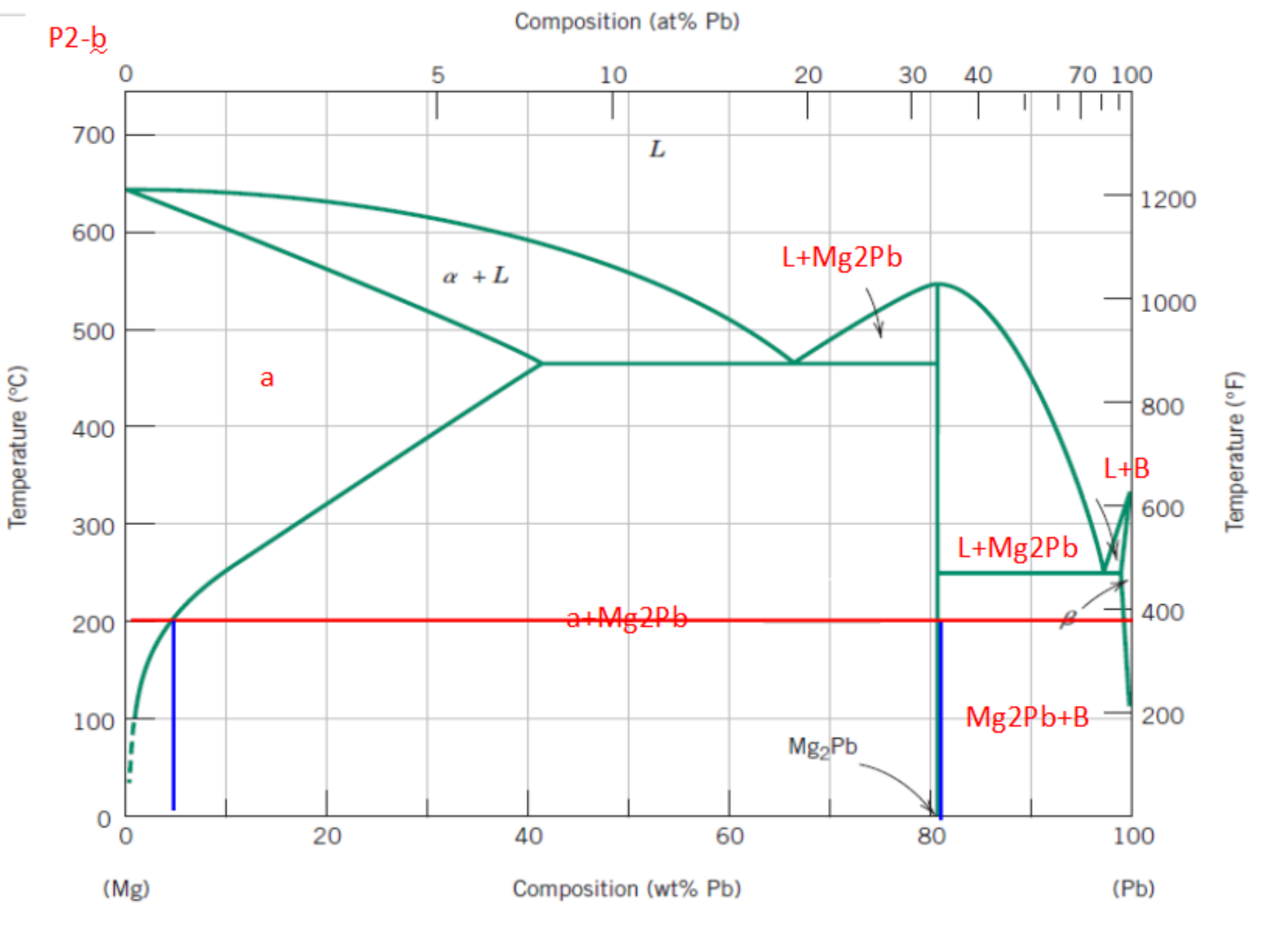
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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a+Mg2Pb
Mg2Pb+B
Mg2Pb
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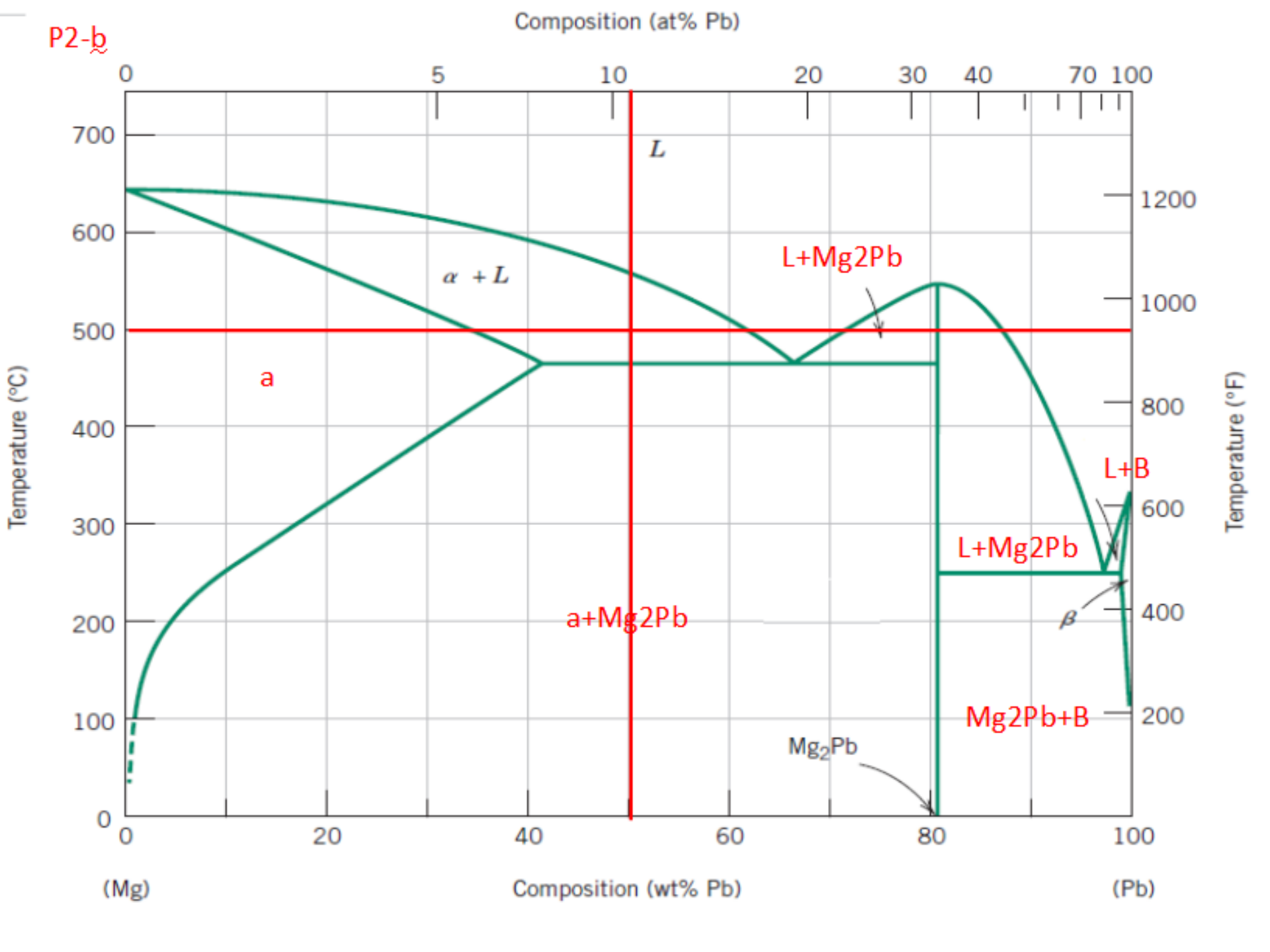
Composition (wt% Pb)
(Pb)

P2-b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a+Mg2Pb
β
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Mg2Pb
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Temperature (°C)
Temperature (°F)
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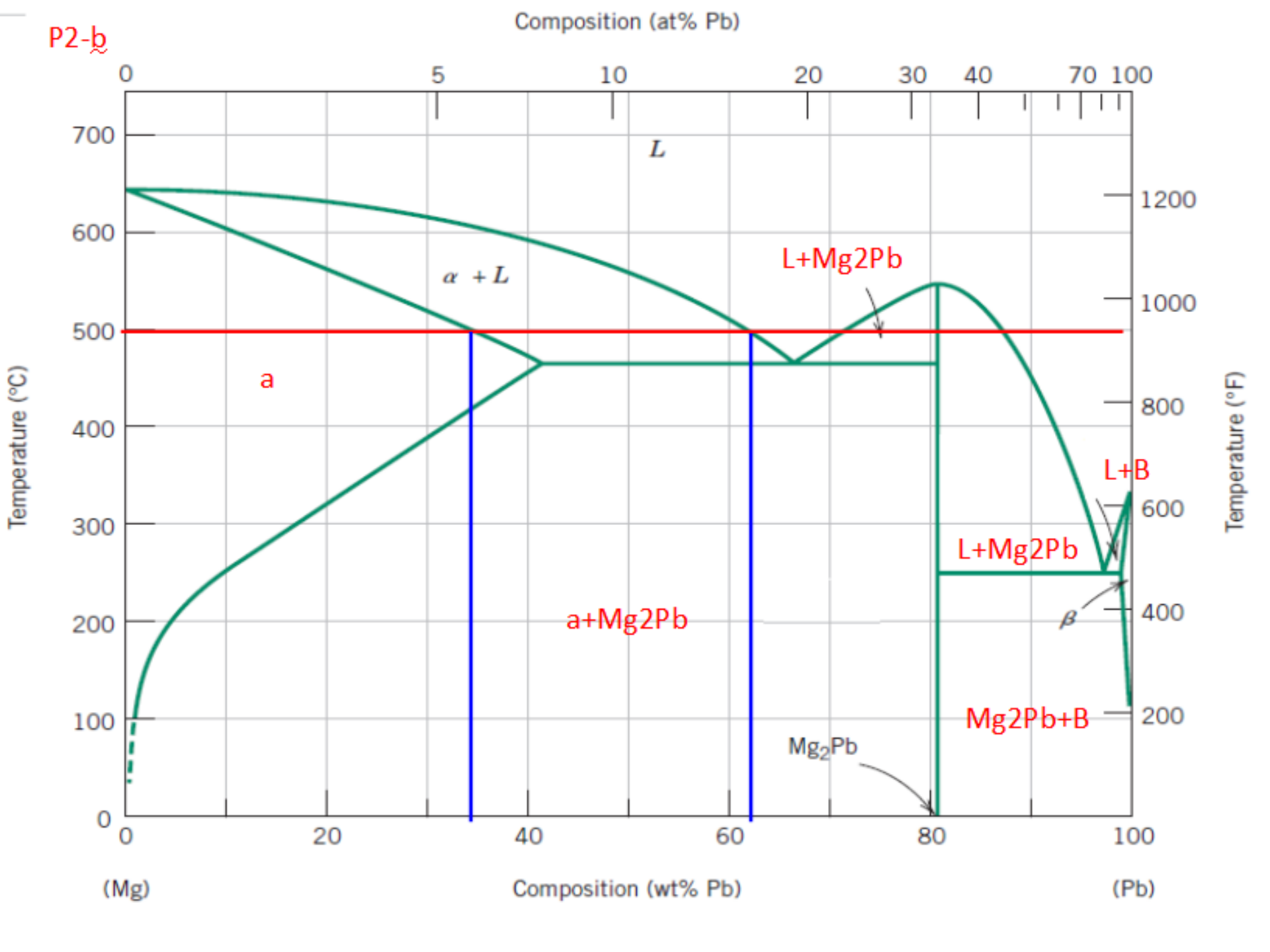
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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L+B
L+Mg2Pb
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Mg2Pb
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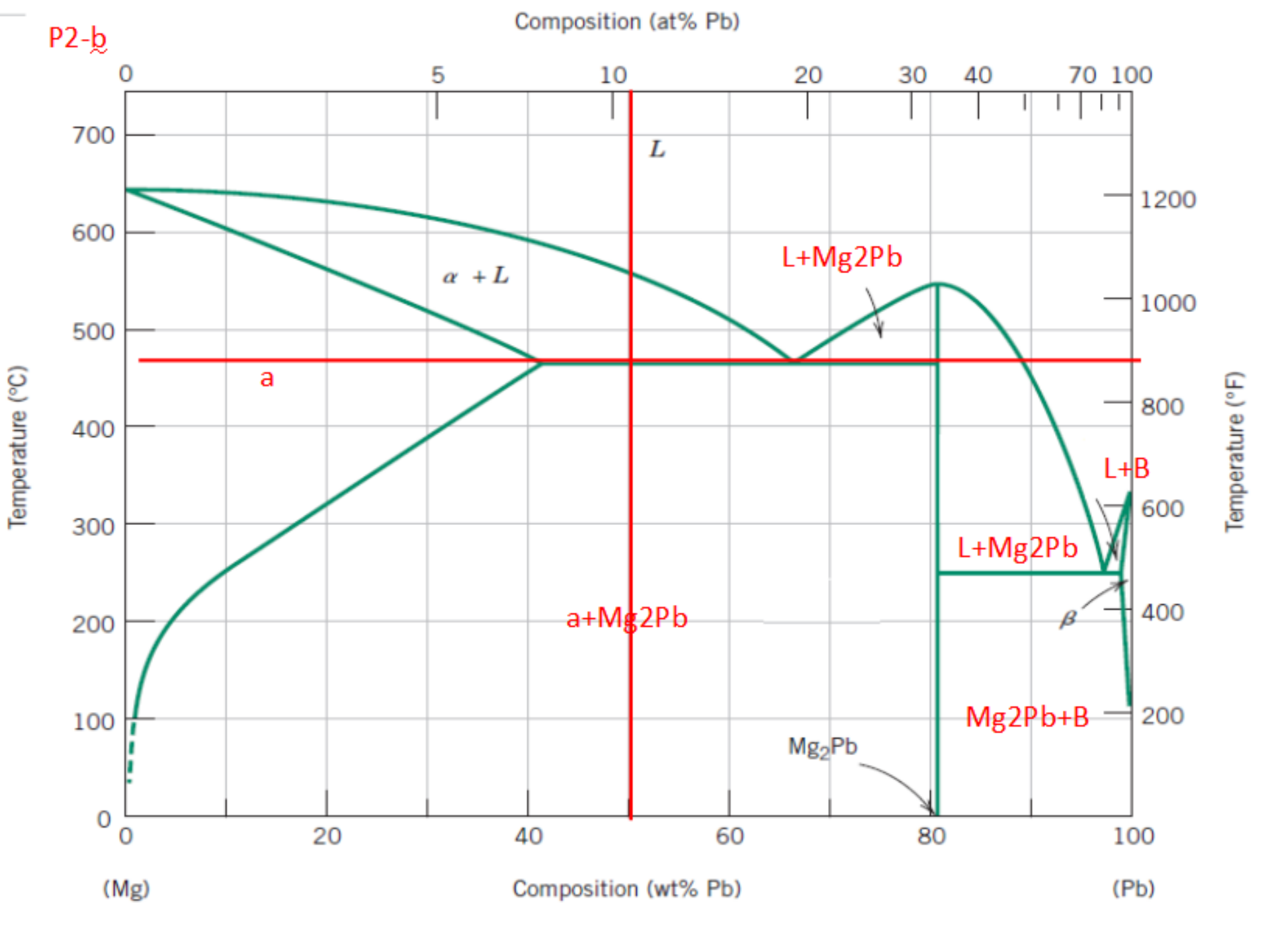
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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L+Mg2Pb
a
a+Mg2Pb
L+B
L+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
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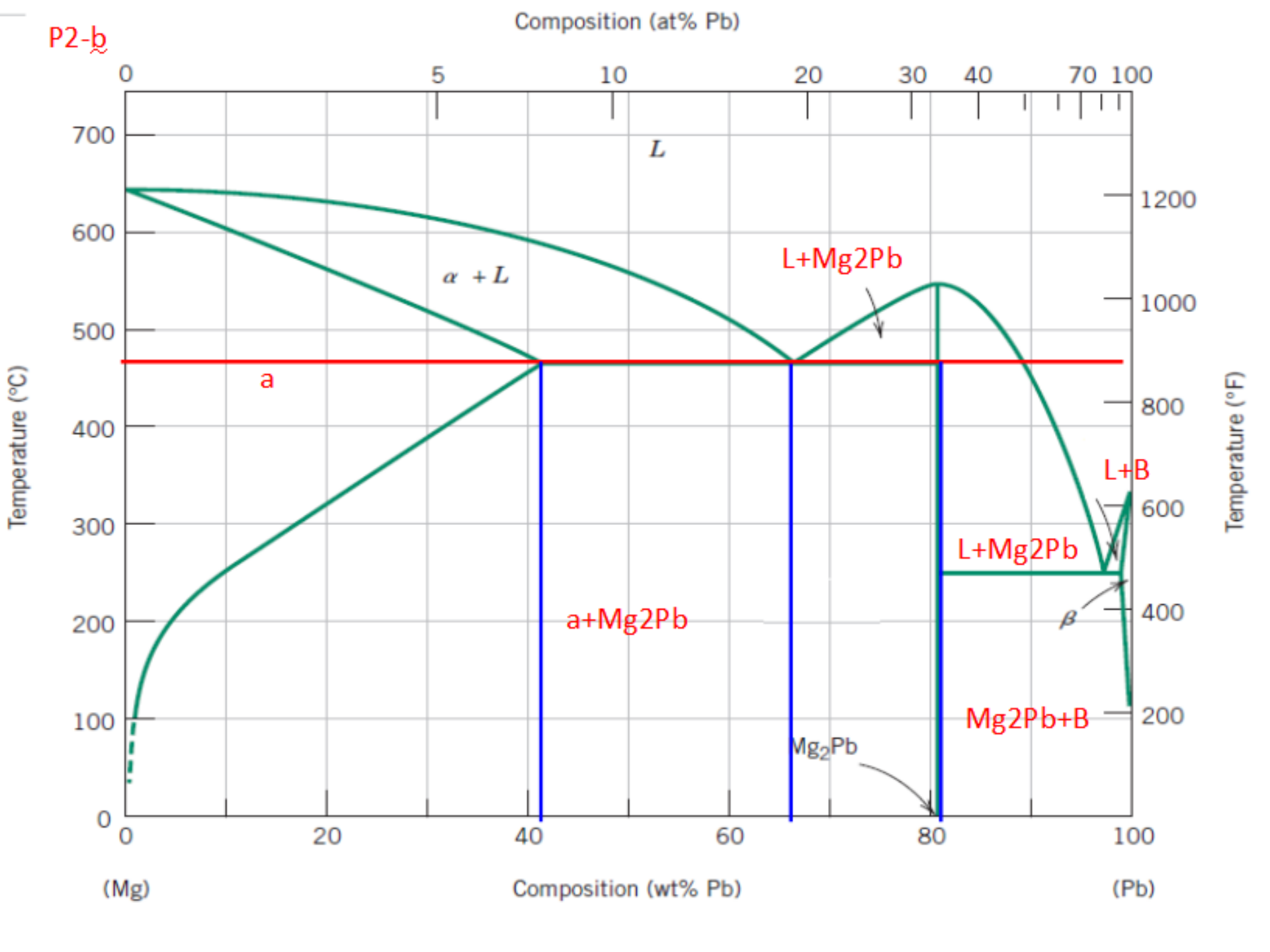
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
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400
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Temperature (°C)
Temperature (°F)
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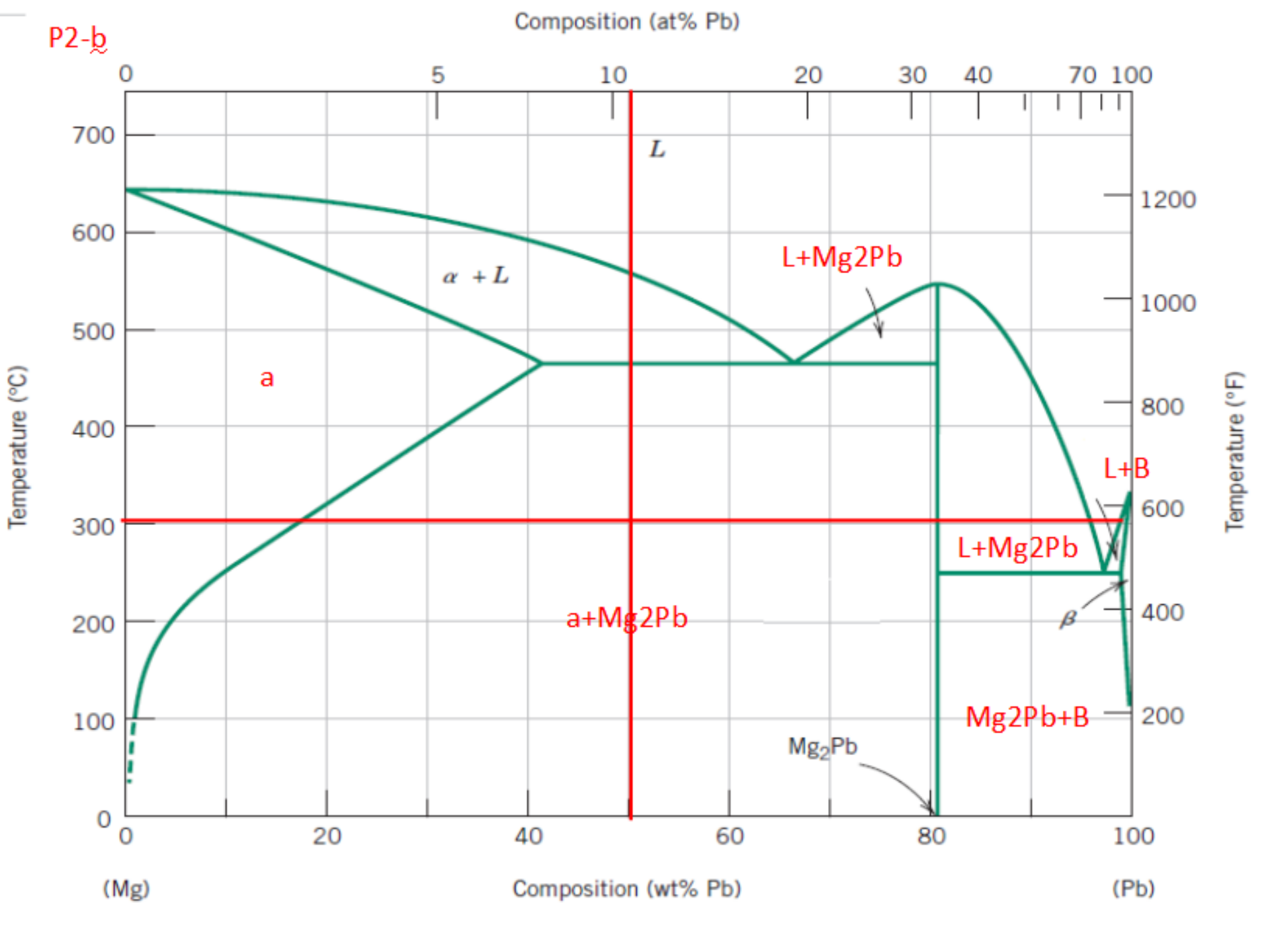
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
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Temperature (°C)
Temperature (°F)
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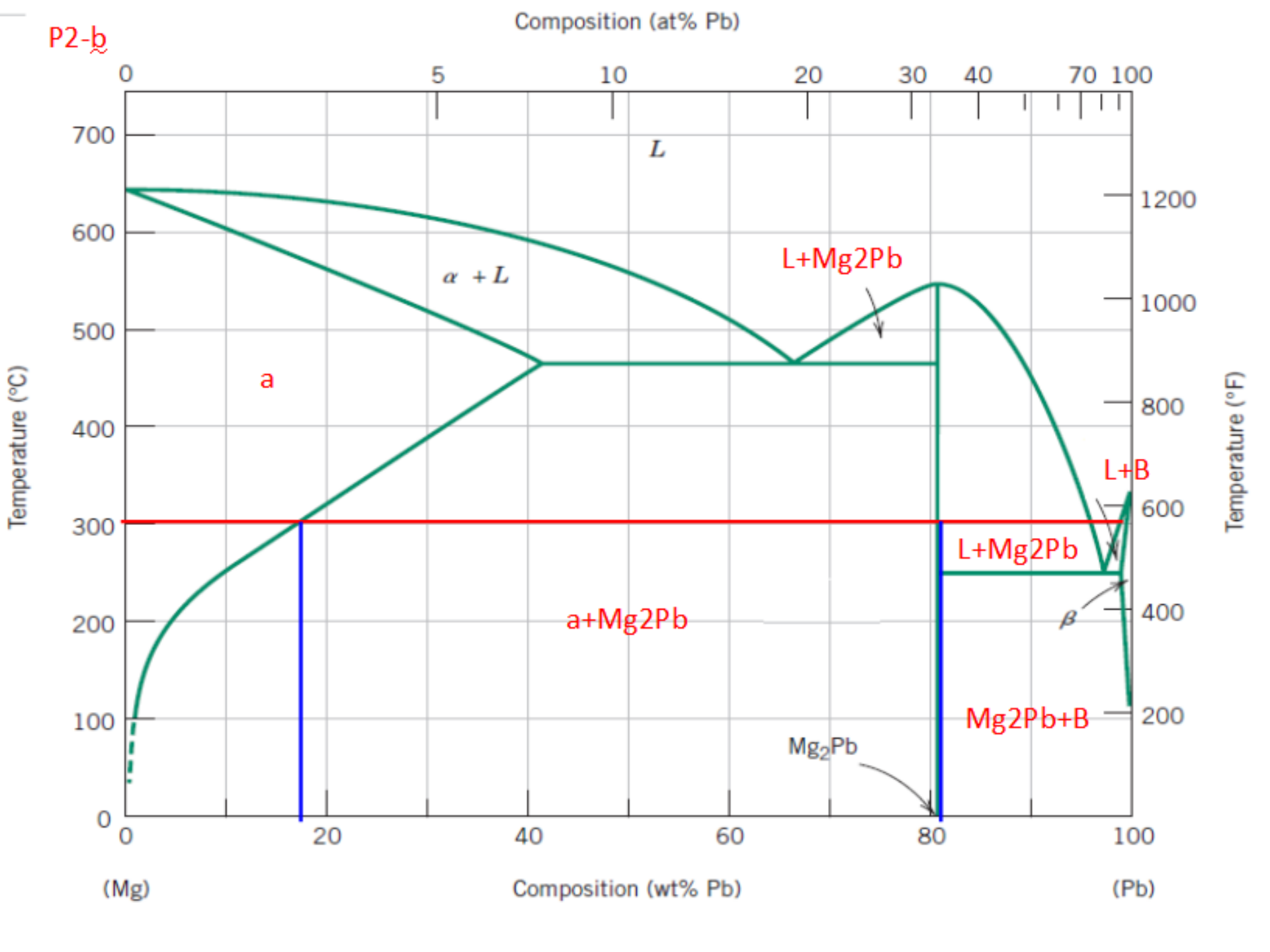
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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200
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α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
Temperature (°C)
Temperature (°F)
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200
0
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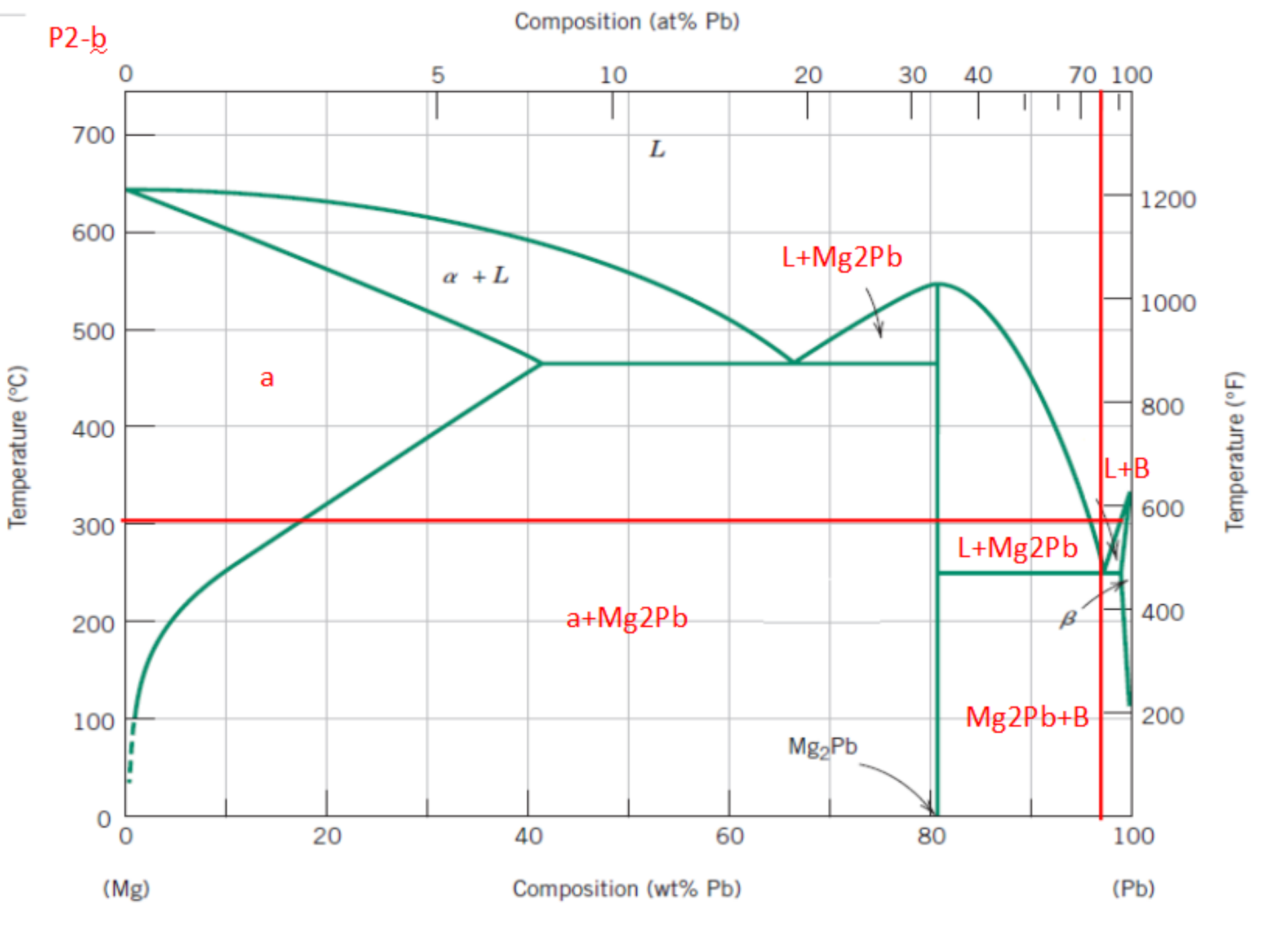
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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a
L+Mg2Pb
L+B
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a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
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Temperature (°F)
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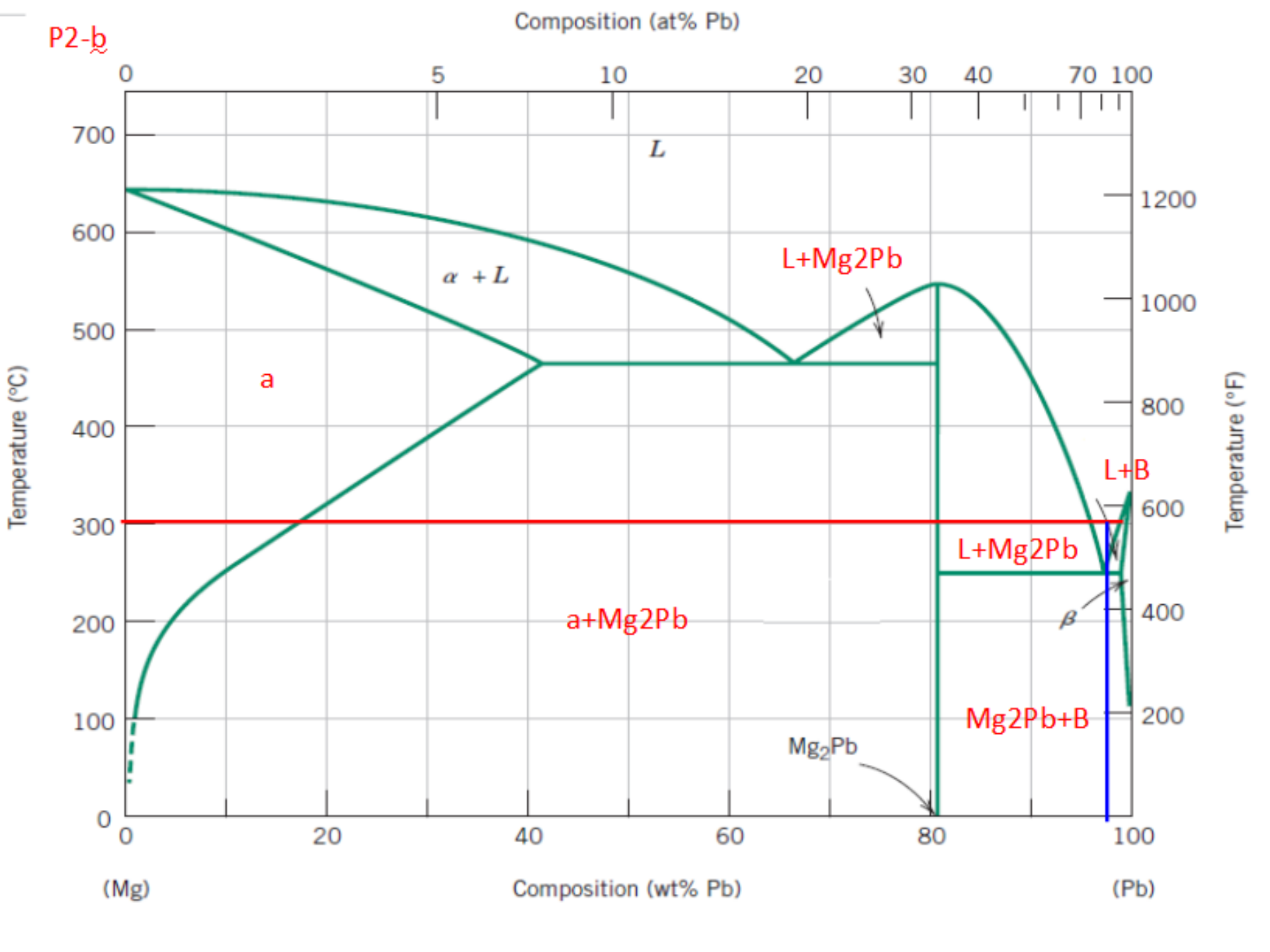
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b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700
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100
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α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
Temperature (°C)
Temperature (°F)
1200
1000
800
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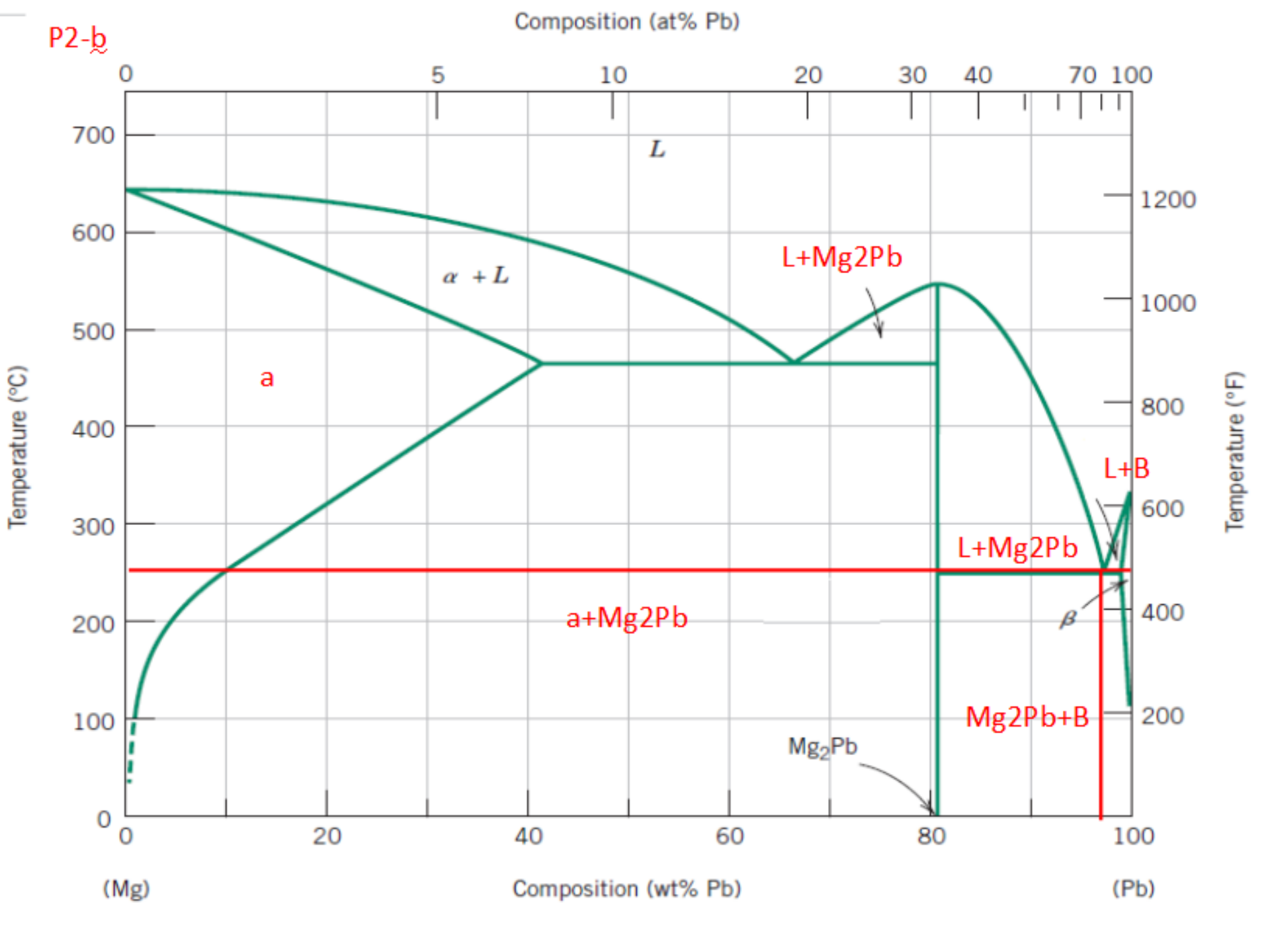
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

P2-b


Composition (at% Pb)
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20
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40
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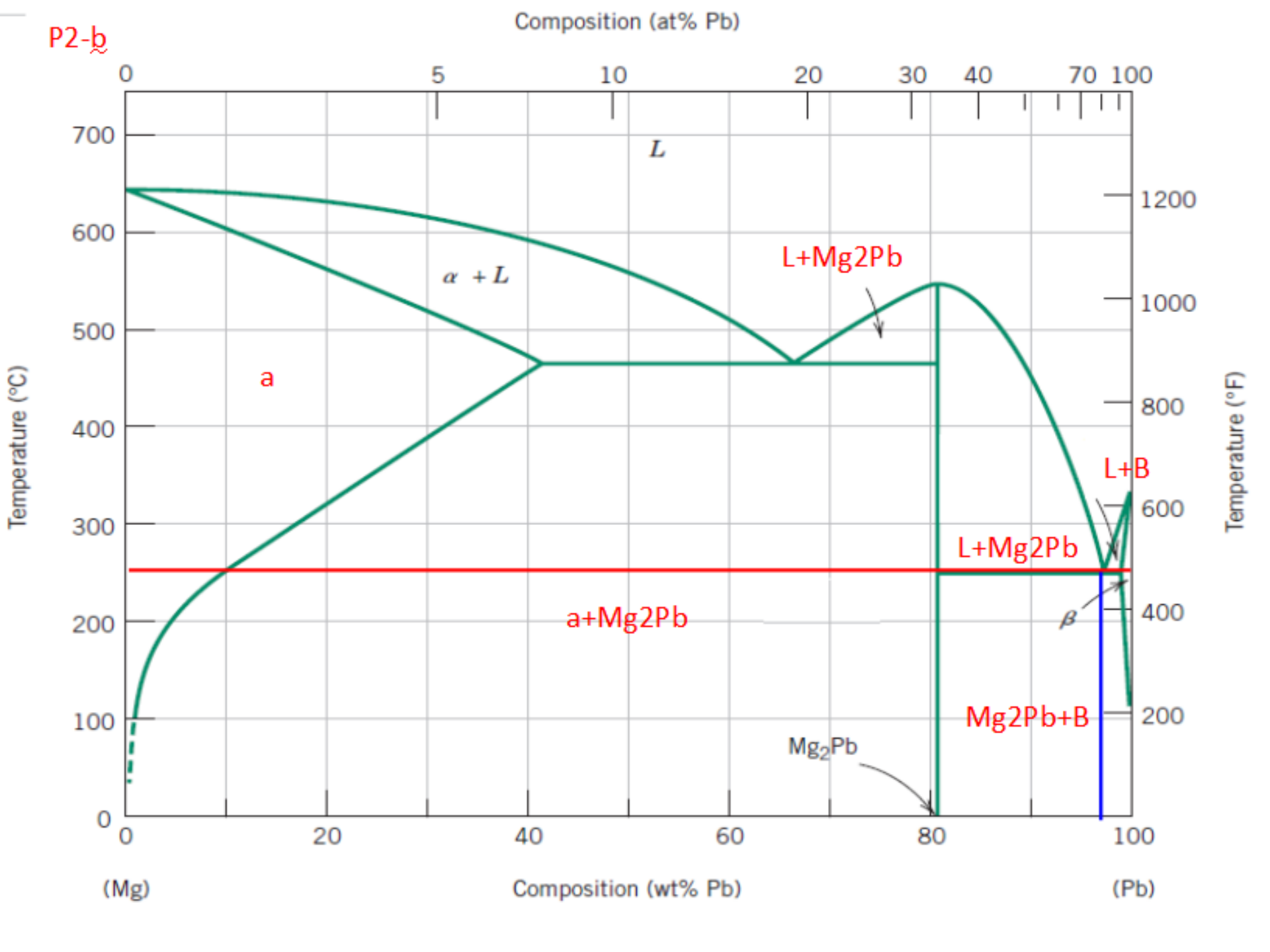
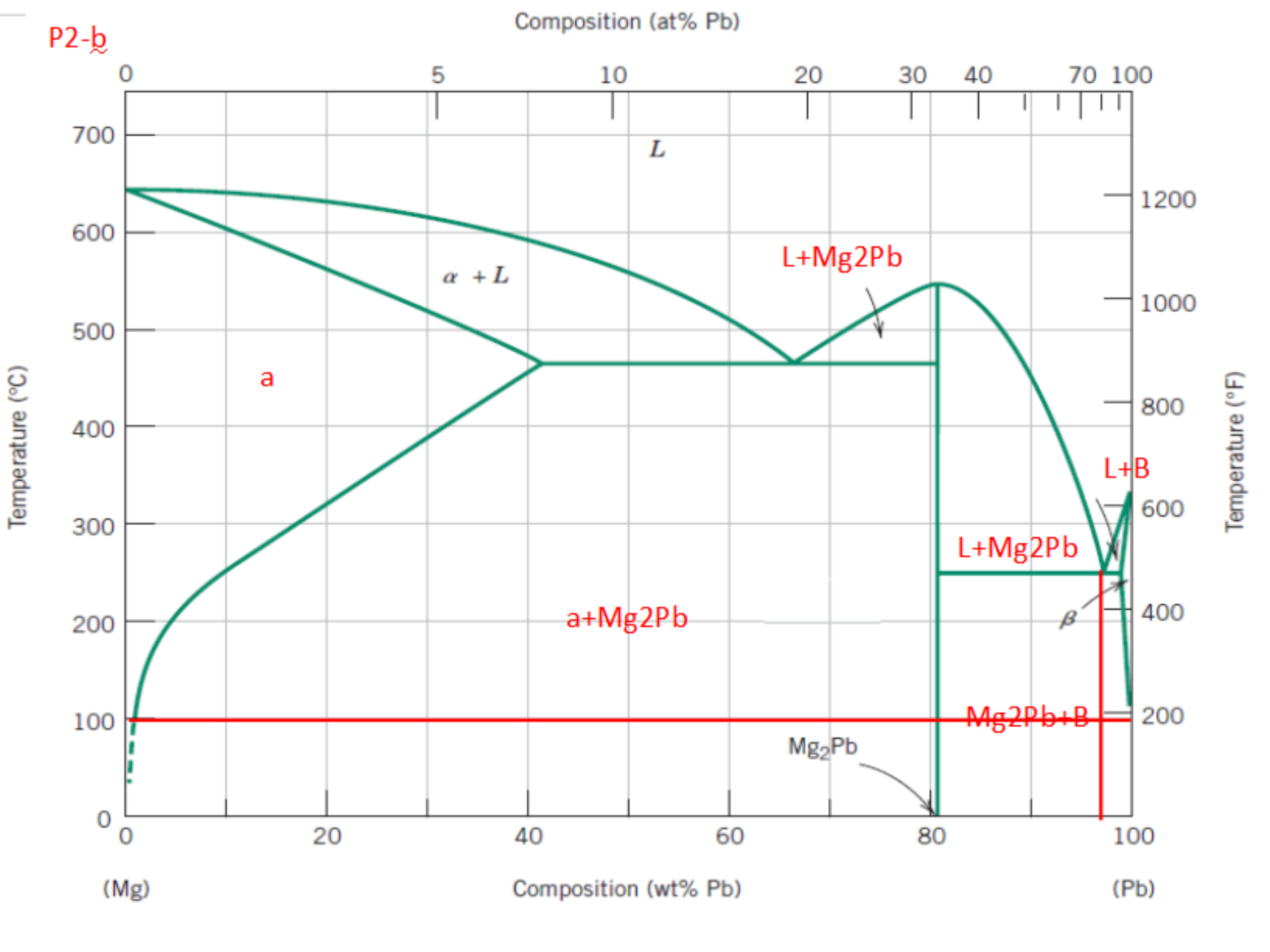
100
700
600
500
400
300
200
100
0
L
α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
600
400
200
Temperature (°C)
Temperature (°F)
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

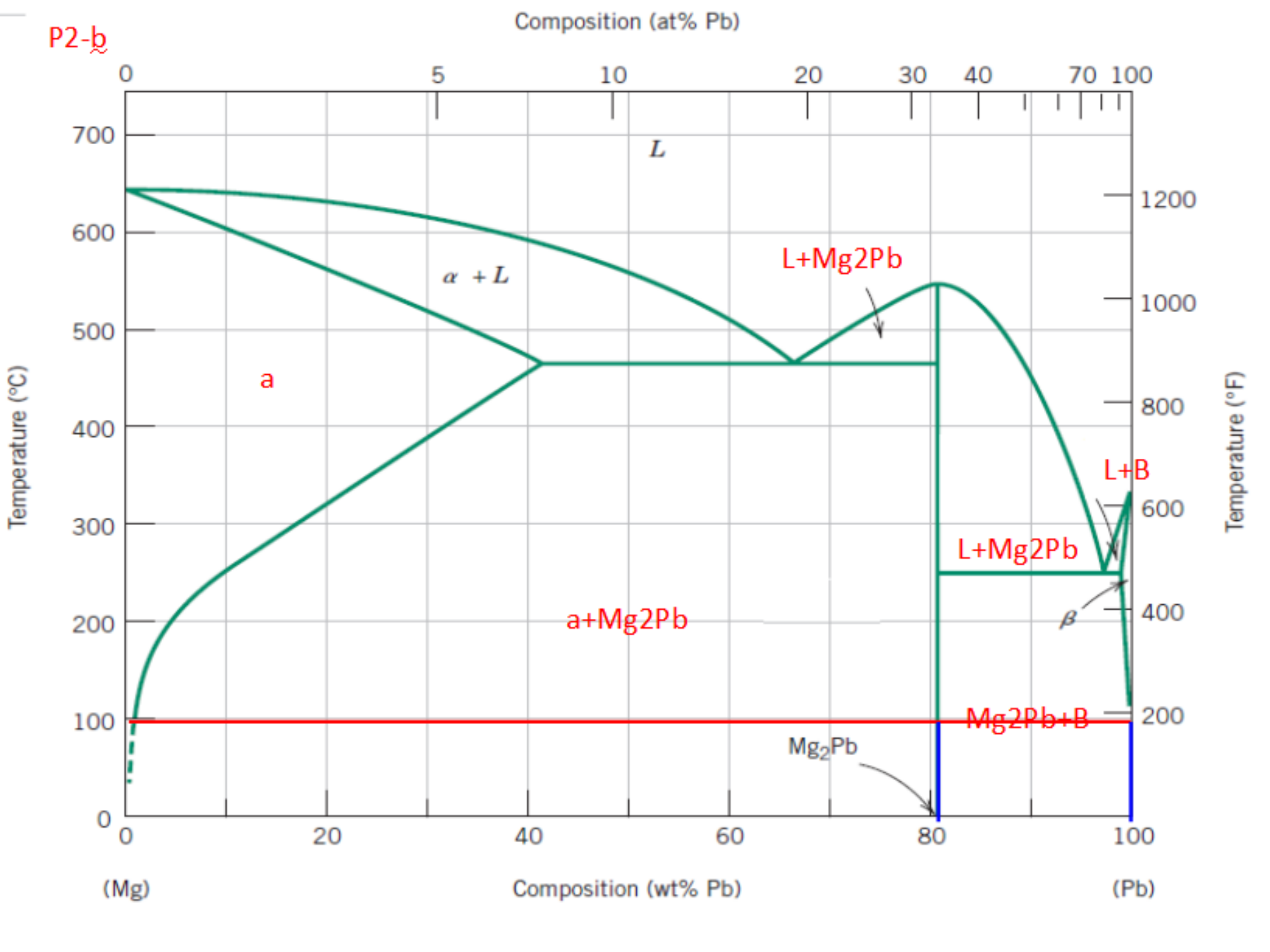
P2-b


Composition (at% Pb)
0
5
10
20
30
40
70
100
700
600
500
400
300
200
100
0
L
α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
Temperature (°C)
Temperature (°F)
1200
1000
800
600
400
200
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

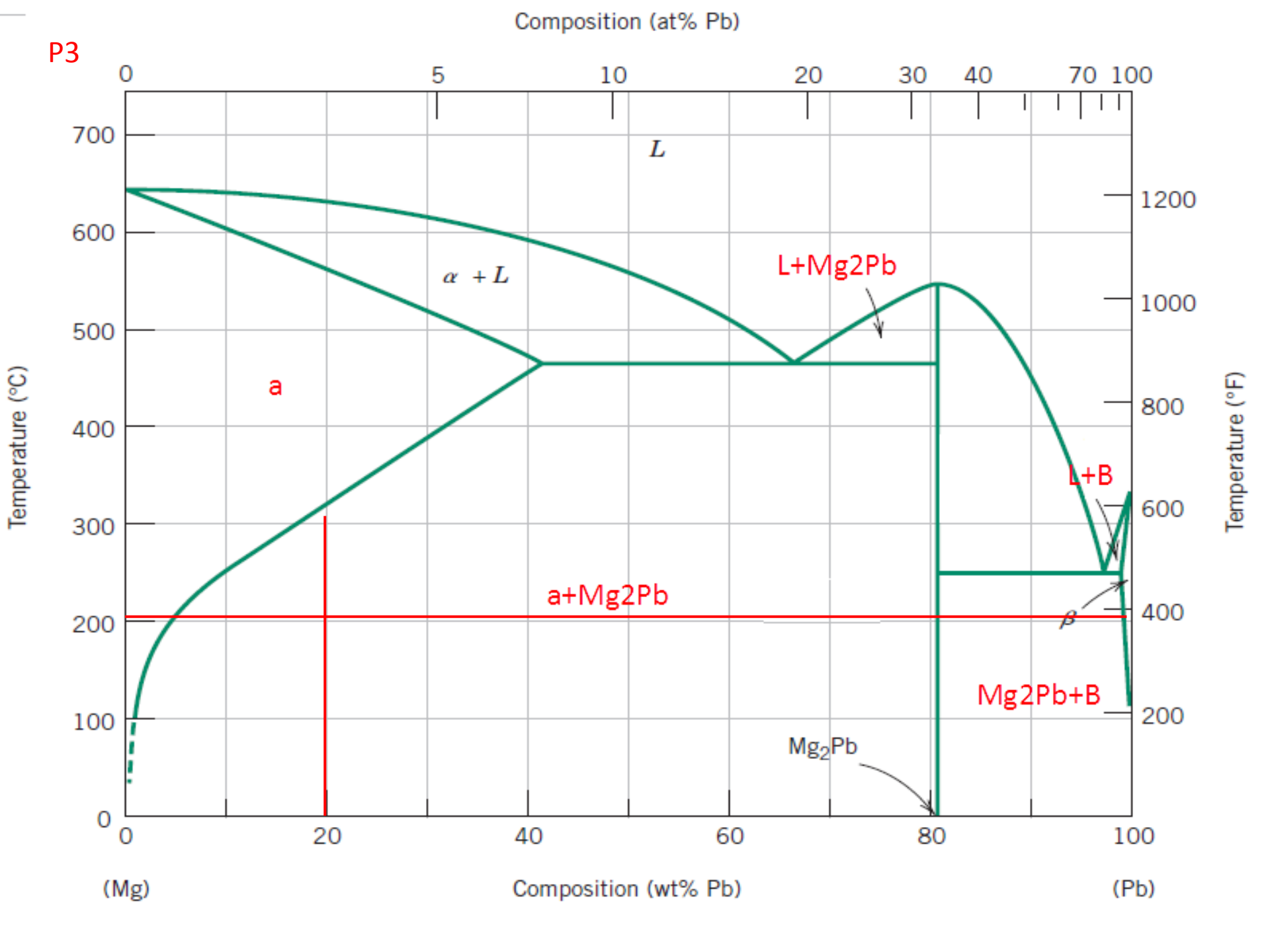
P2-b


Composition (at% Pb)
0
5
10
20
30
40
70
100
700
600
500
400
300
200
100
0
L
α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
600
400
200
Temperature (°C)
Temperature (°F)
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

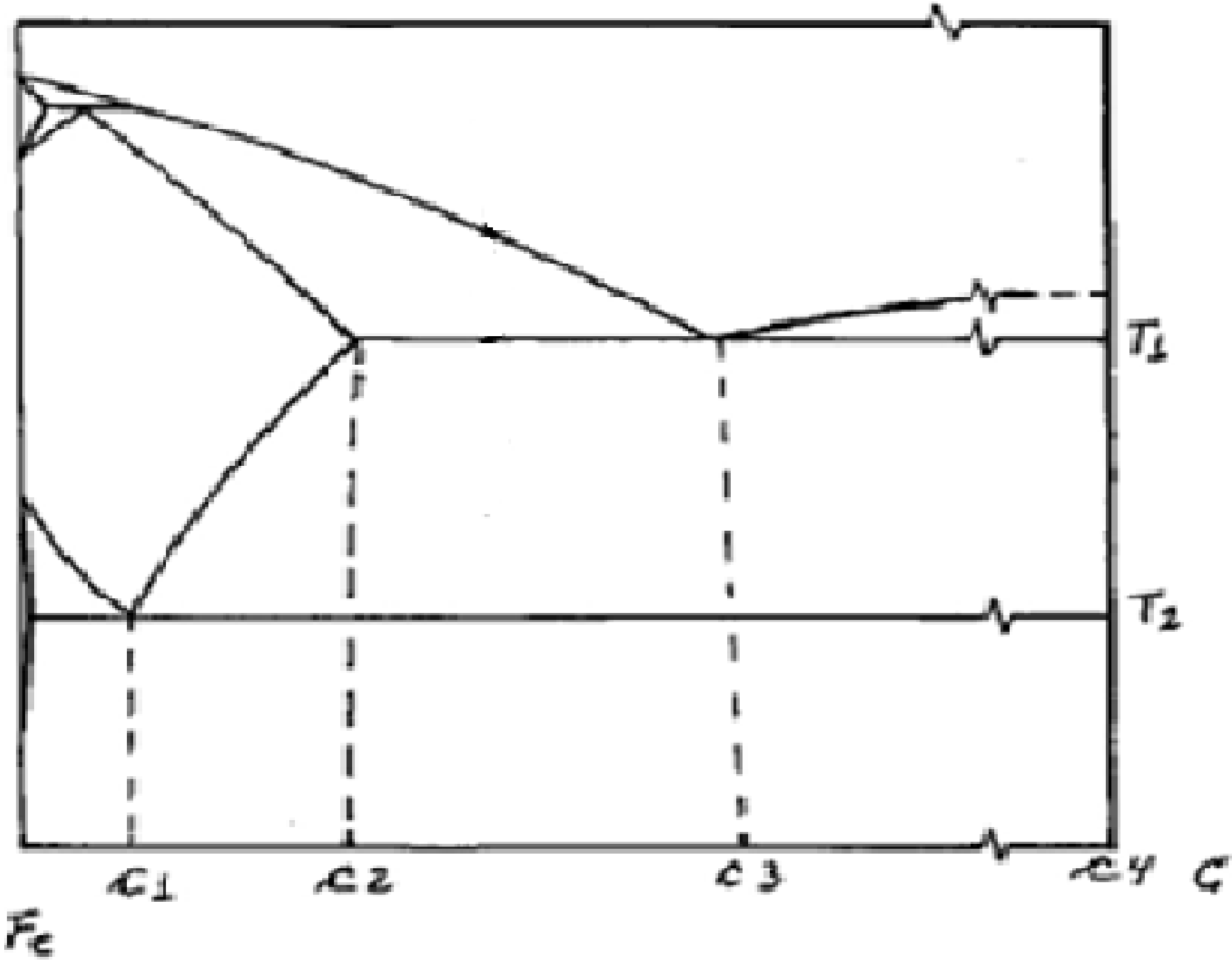
P2-b


Composition (at% Pb)
0
5
10
20
30
40
70
100
700
600
500
400
300
200
100
0
L
α + L
a
L+Mg2Pb
L+B
L+Mg2Pb
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
600
400
200
Temperature (°C)
Temperature (°F)
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

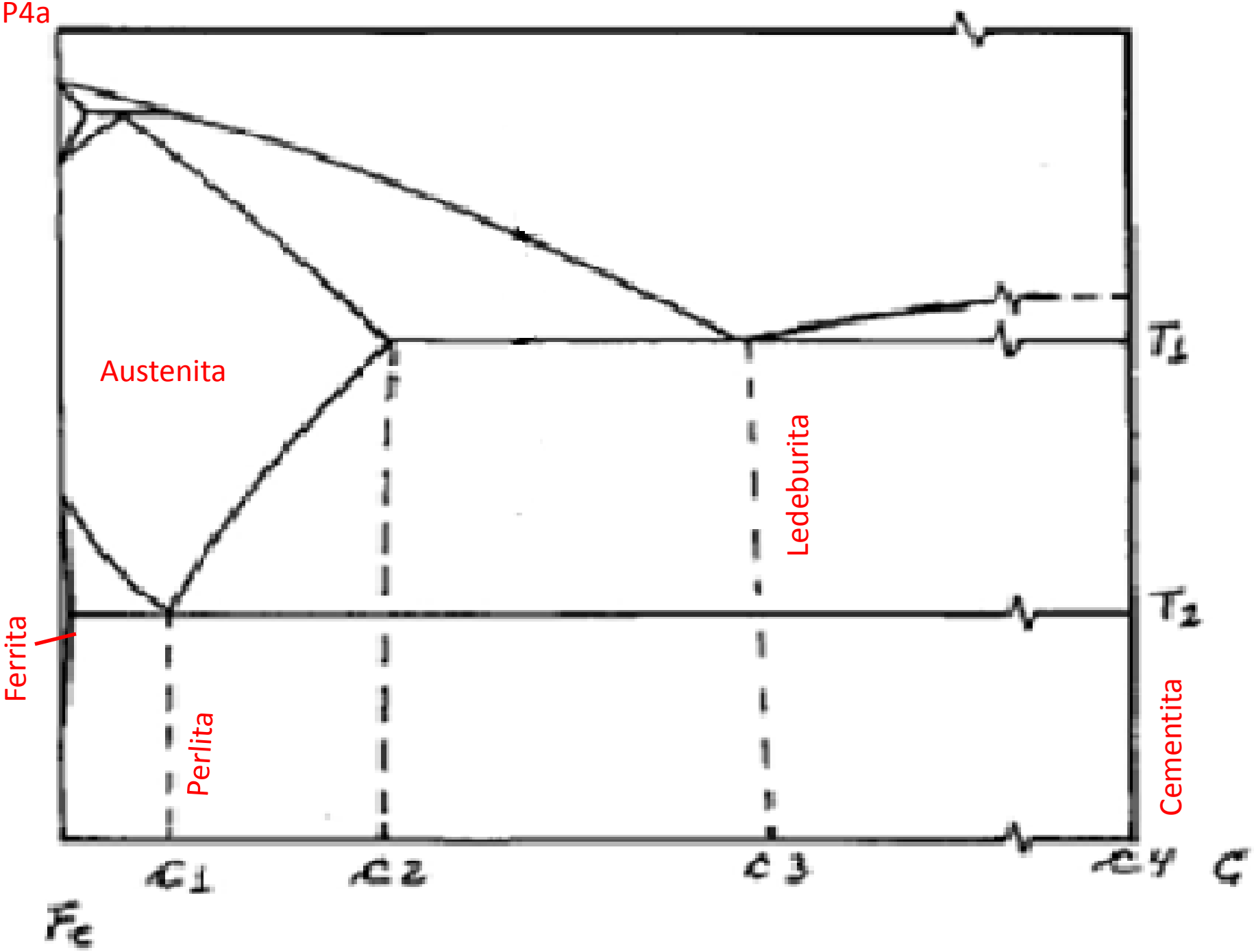
P3


Composition (at% Pb)
0
5
10
20
30
40
70
100
700
600
500
400
300
200
100
0
L
α + L
a
L+Mg2Pb
L+B
a+Mg2Pb
β
Mg2Pb+B
Mg2Pb
1200
1000
800
600
400
200
Temperature (°C)
Temperature (°F)
0
20
40
60
80
100
(Mg)
Composition (wt% Pb)
(Pb)

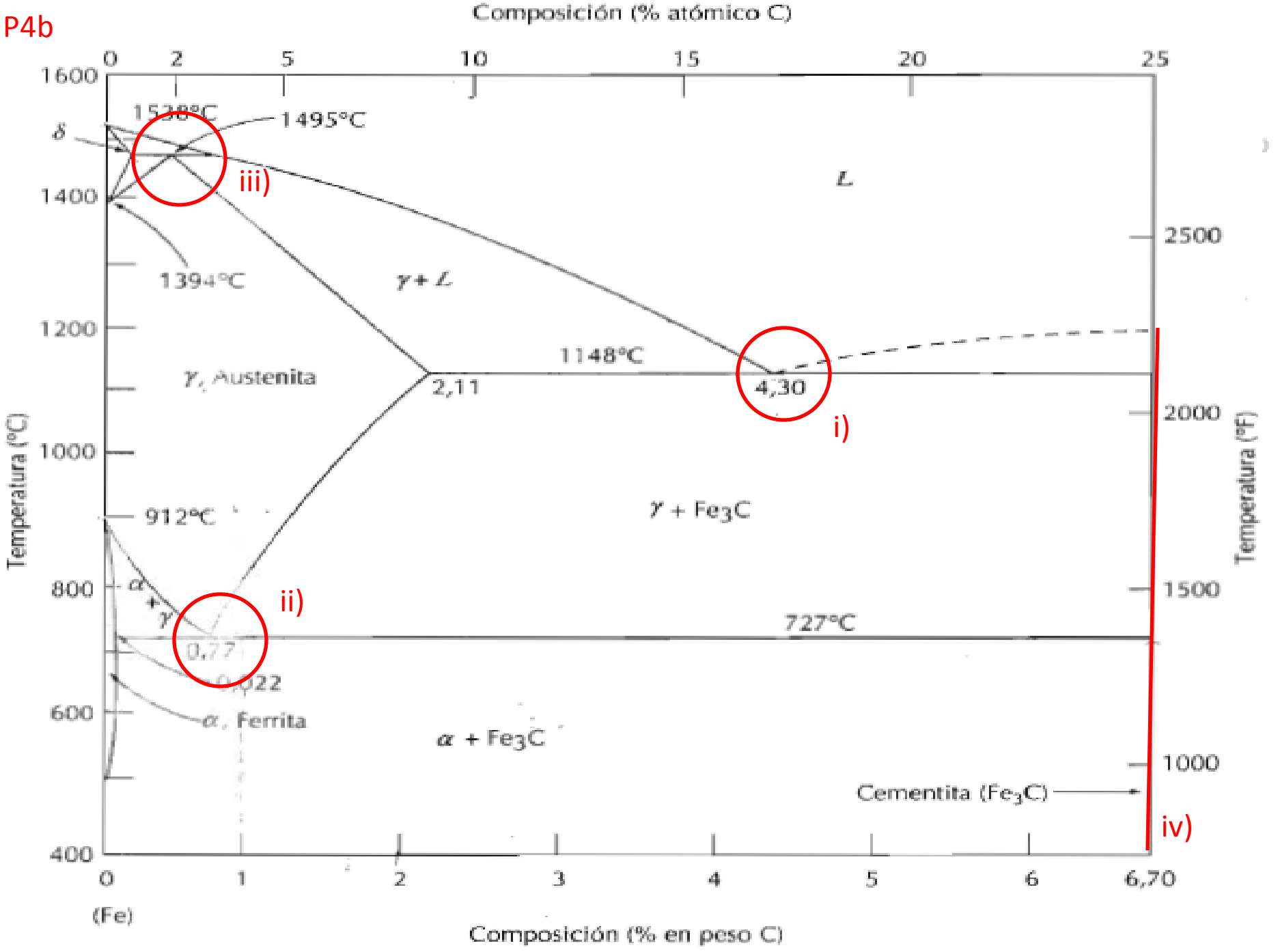
P4



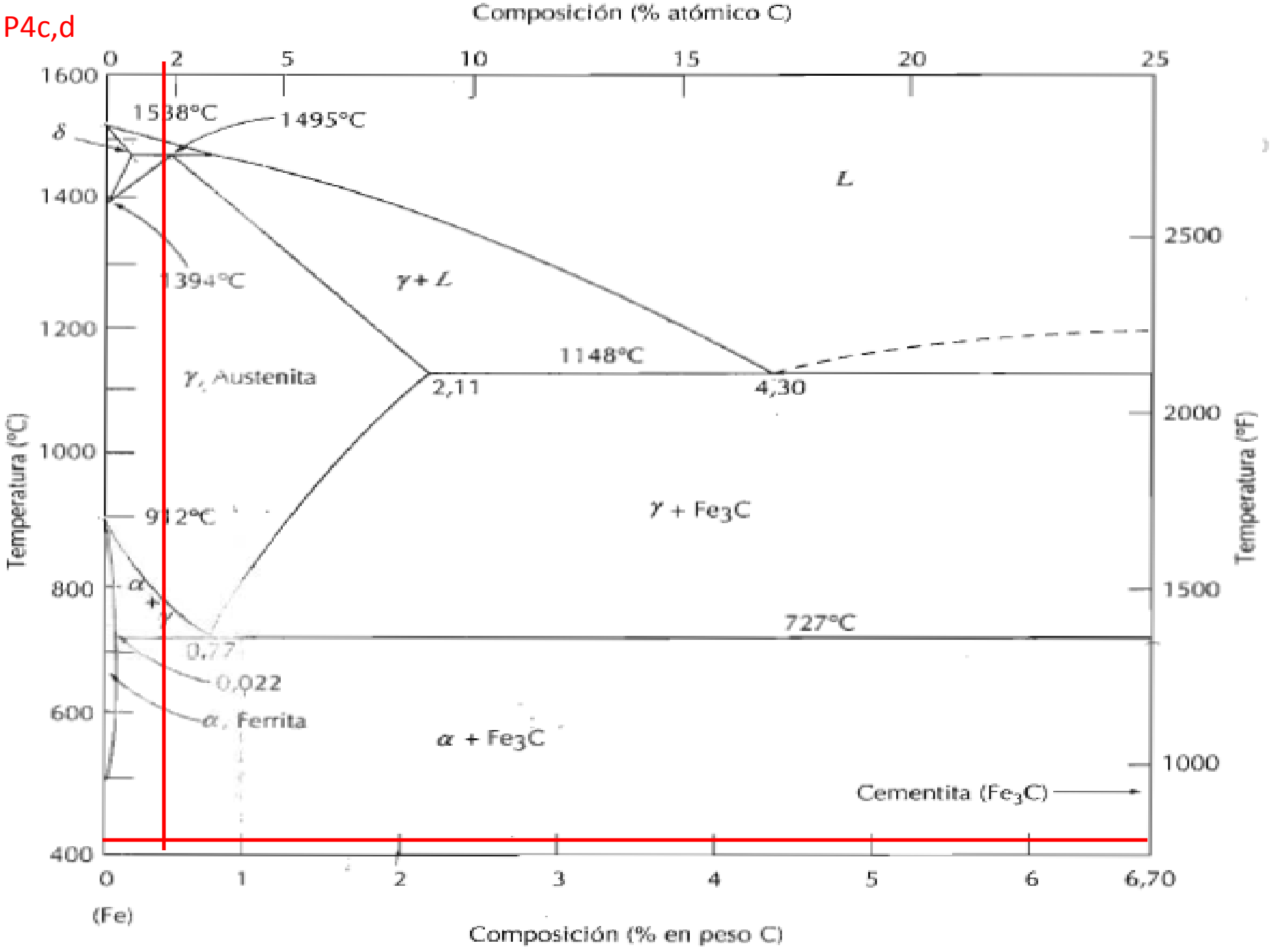
P4a


Austenita
Ledeburita
Ferrita
Perlita
Cementita
T1
T2
C1
C2
C3
C4
C
Fe

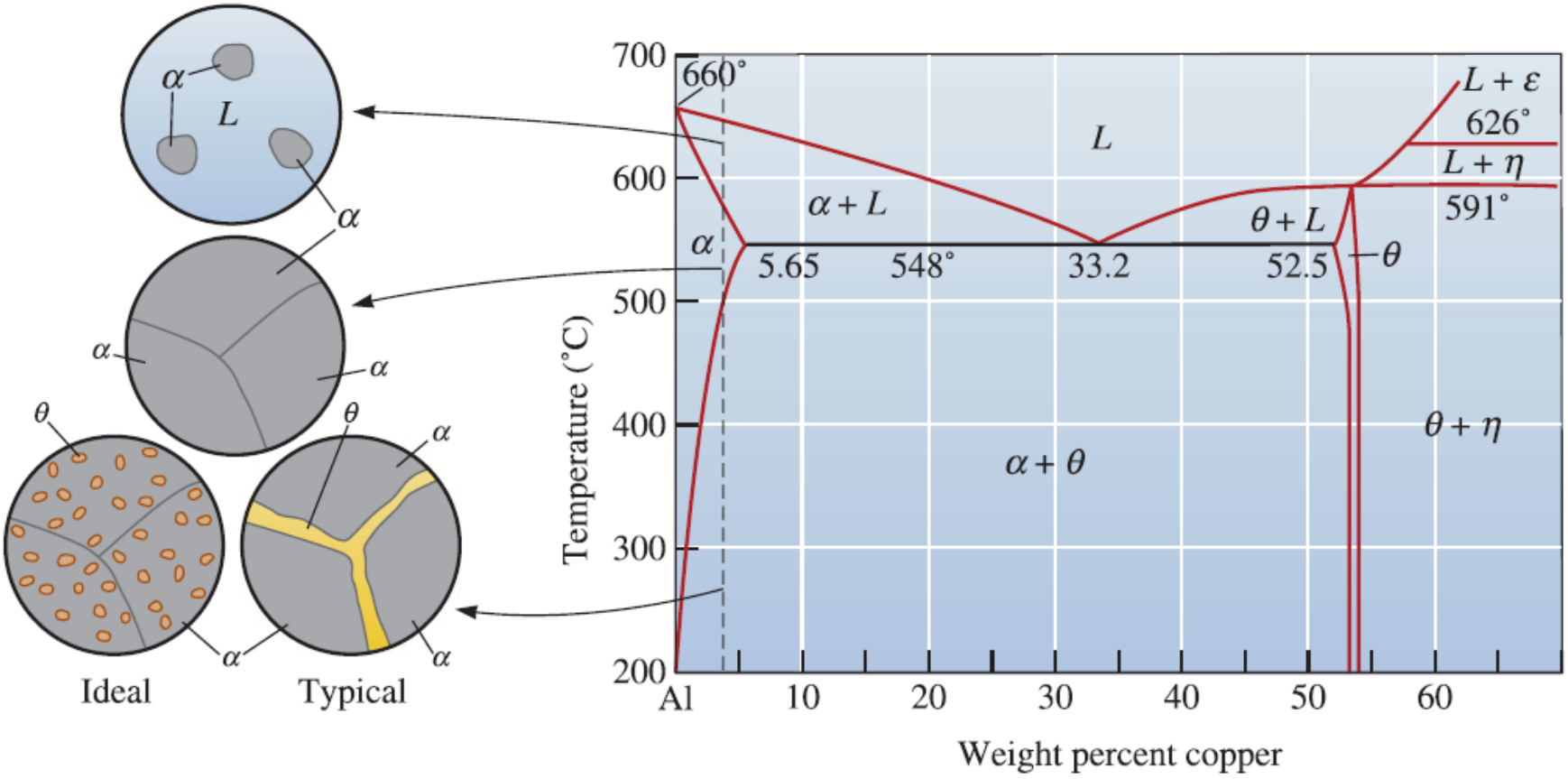
P4b


Composición (% atómico C)
0
2
5
10
15
20
25
1600
1400
1200
1000
800
600
400
1538°C
1495°C
δ
L
iii)
1394°C
γ + L
2500
2000
1500
1000
1148°C
γ, Austenita
2,11
4,30
i)
912°C
γ + Fe3C
α + γ
ii)
727°C
0,77
0,022
α, Ferrita
α + Fe3C
Cementita (Fe3C)
iv)
Temperatura (°C)
Temperatura (°F)
0
1
2
3
4
5
6
6,70
(Fe)
Composición (% en peso C)

P4c,d


Composición (% atómico C)
0
2
5
10
15
20
25
1600
1400
1200
1000
800
600
400
1538°C
1495°C
δ
L
1394°C
γ + L
2500
2000
1500
1000
1148°C
γ, Austenita
2,11
4,30
912°C
γ + Fe3C
α + γ
727°C
0,77
0,022
α, Ferrita
α + Fe3C
Cementita (Fe3C)
Temperatura (°C)
Temperatura (°F)
0
1
2
3
4
5
6
6,70
(Fe)
Composición (% en peso C)

Crecimiento de Precipitados



Nucleacion de precipitados en estado sólido

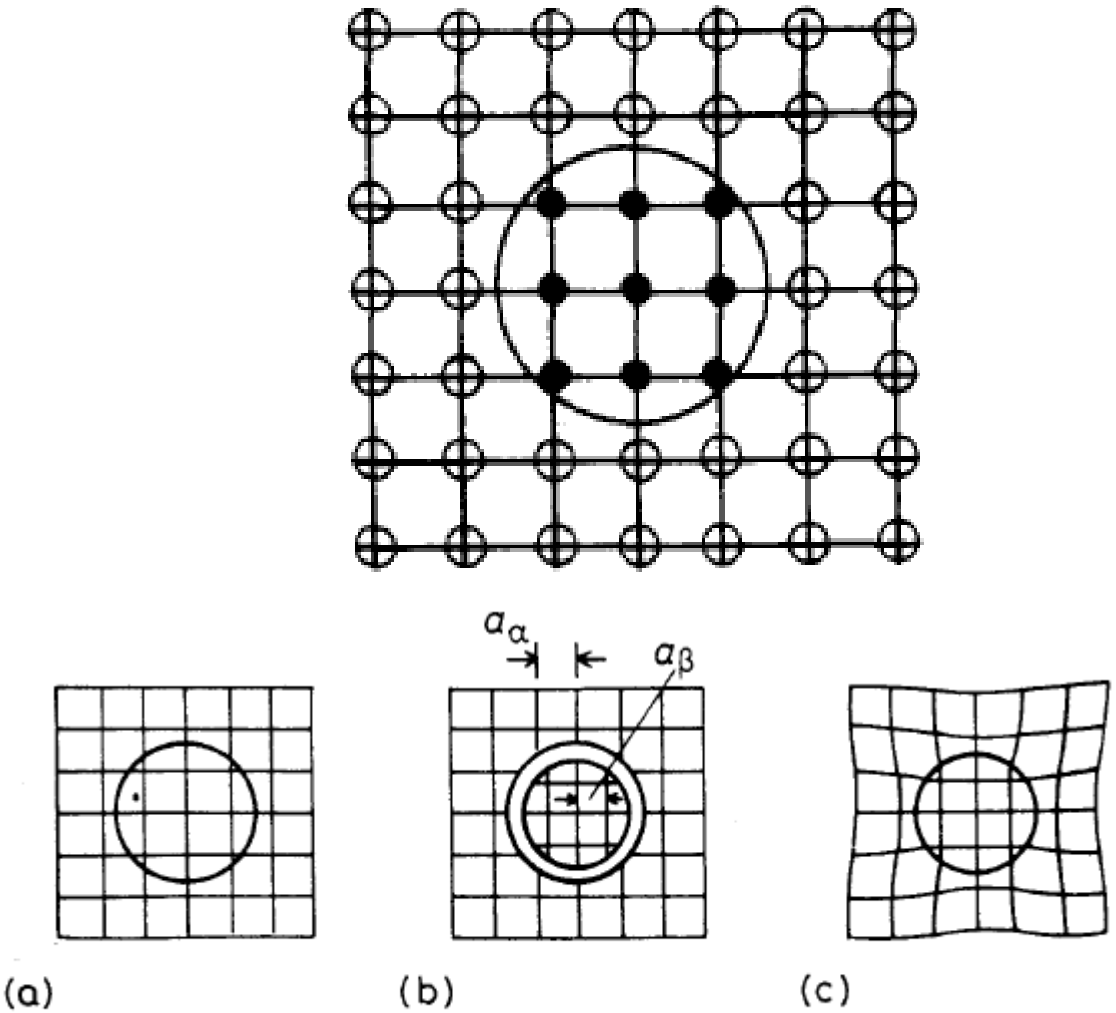


Fig. 3.47 The origin of coherency strains. The number of lattice points in the hole is conserved.

Coherencia de precipitados

Coherente

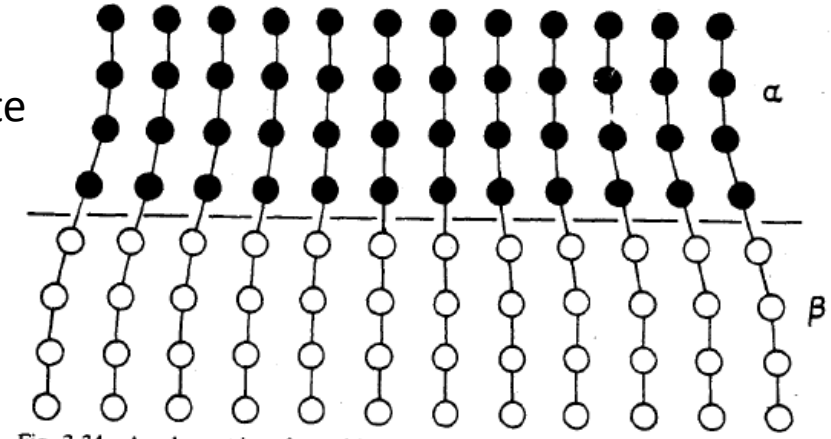


Fig. 3.34 A coherent interface with slight mismatch leads to coherency strains in the adjoining lattices.

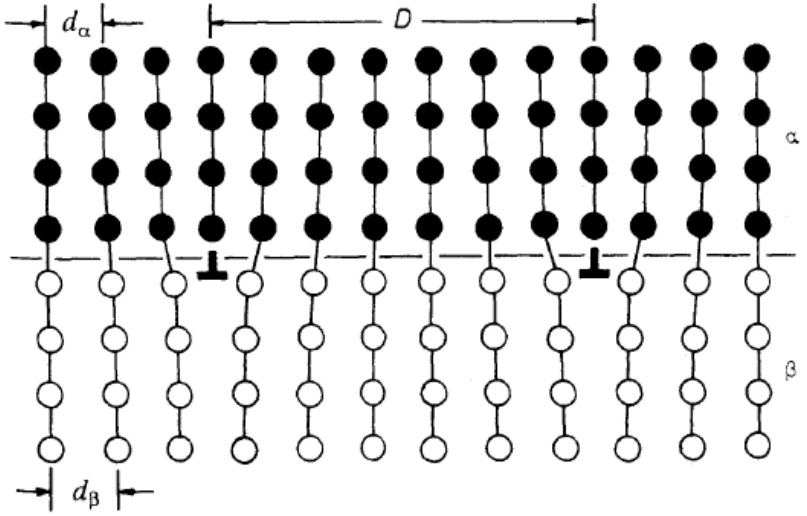


Fig. 3.35 A semicoherent interface. The misfit parallel to the interface is accommodated by a series of edge dislocations.

Semicoherente

Incoherente

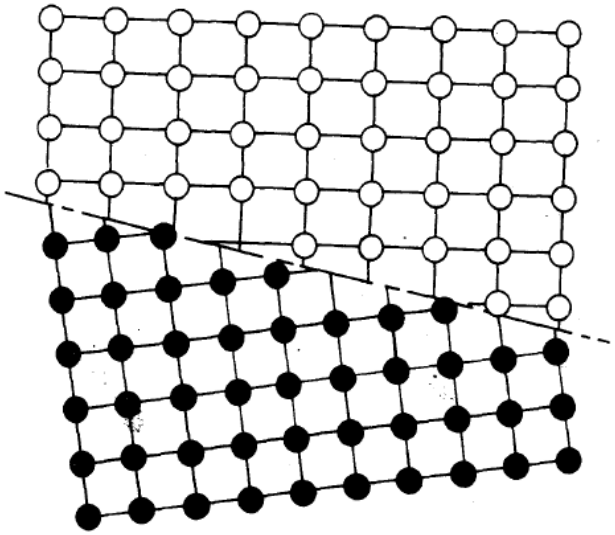


Fig. 3.37 An incoherent interface.