Homework 0

Carefully review chapter 9, 11, and 12 lecture slides and, if time allows, read textbook sections of Askeland 9.1-9.13; 11.1-11.7; 12.2-12.8, 12.10-12.12 (some numerical example problems such as 9-1 to 9-8, 12-1, 12-7 to 12-10 could be omitted) and give an honor statement confirming the reading

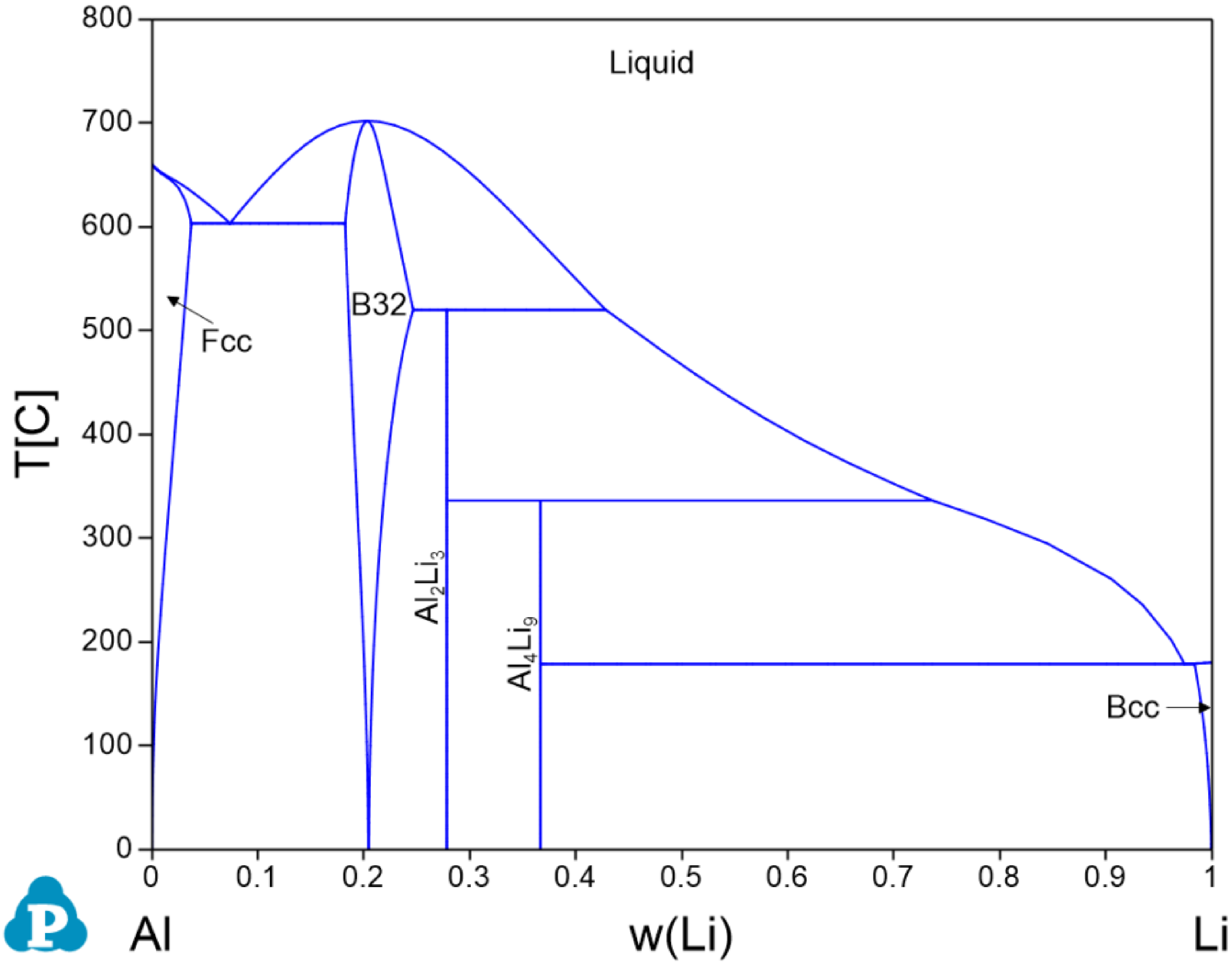
Homework 1

- Please write down one (or more) question that you are not clear or feel interested about in these three chapters (Chapters 9, 11, & 12).
- Check for answers using any AI tool and give brief comments on **your challenge to or suspicion of** the answer given by the AI.

Homework 2

Based on the Al-Li phase diagram below, please do the followings:

1) Identify the intermetallics (line compound) that may exist in the Al-Li system
2) Write down the eutectic reaction at around 600C as well as peritectic reactions at both ~520C and 340C in the system.
   Please also write down the estimated composition for each of the phases involved in those reactions.



Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

Homework 2

1) Intermetallic that might exist include B32 (AlLi and solid solution close to it), Al_2Li_3, Al_4Li_9

2) Eutectic reaction at ~610^{o}C:

   L = Fcc + B32

   Composition for each of the phases:

   C(L) = 7.5 wt.% Li

   C(Fcc) = 3.5 wt.% Li

   C(B32) = 18 wt.% Li

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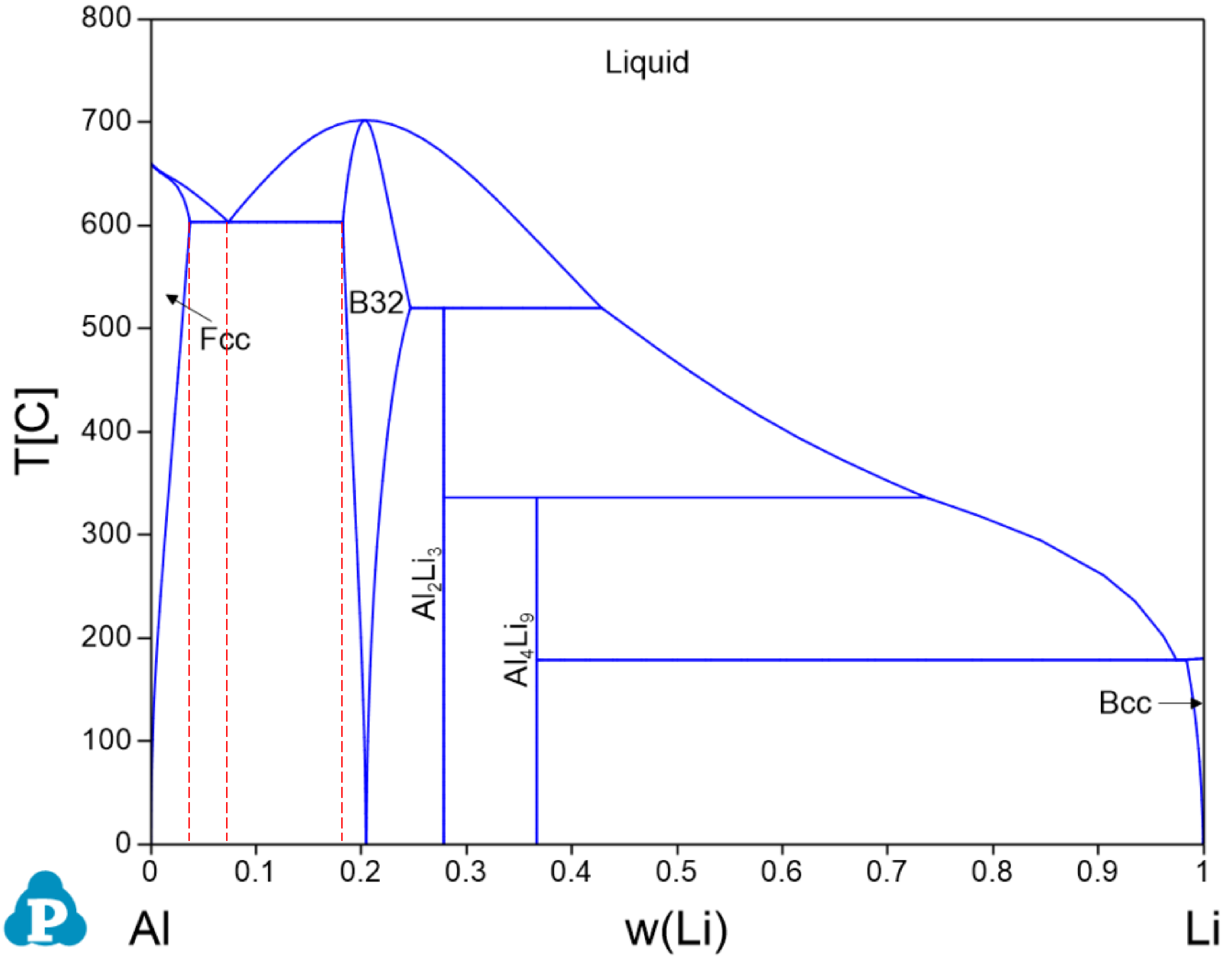


Homework 2

2) Peritectic reaction at ~520°C

B32 + L = Al_2Li_3

Composition for each of the phases:

C(B32) ≈ 24.5 wt.% Li

C(L) ≈ 42.5 wt.% Li

C(Al_2Li_3) ≈ 28 wt.% Li

(6.94×3/(26.98×2+6.94×3) = 27.8%)

Peritectic reaction at ~340°C

Al_2Li_3 + L = Al_4Li_9

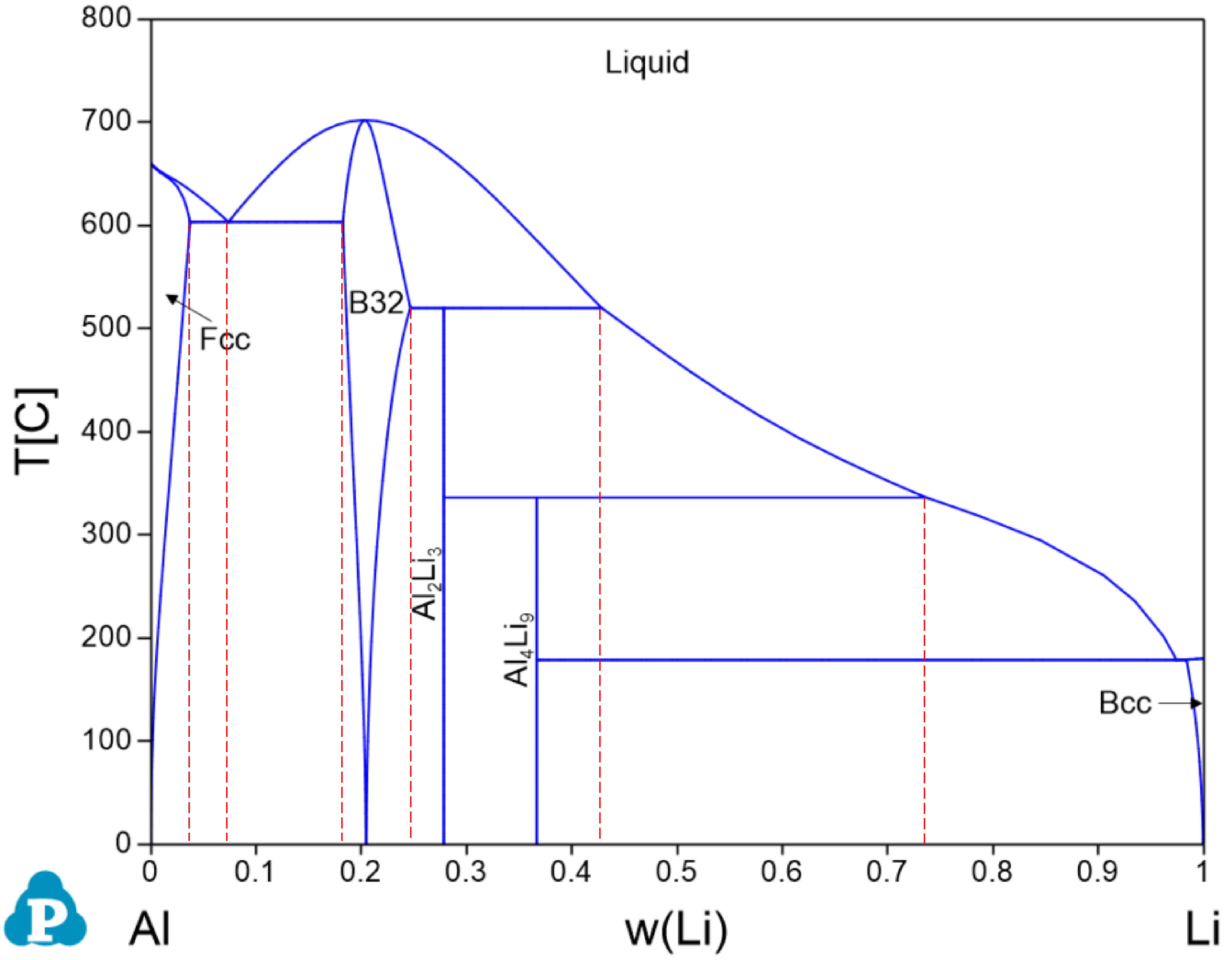
Composition for each of the phases:

C(Al_2Li_3) ≈ 28 wt.% Li

C(L) ≈ 73 wt.% Li

C(Al_4Li_9) ≈ 36.5 wt.% Li

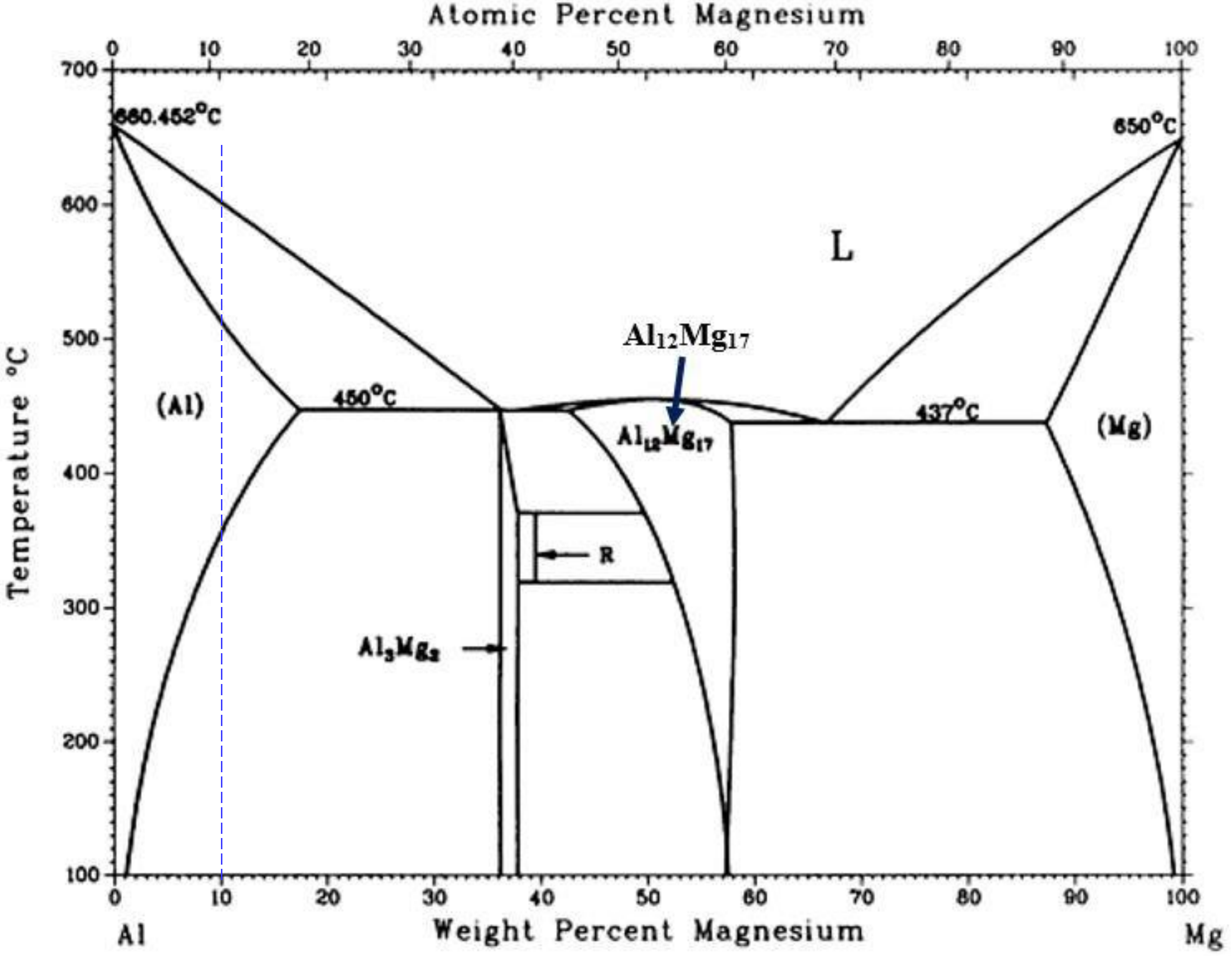
(6.94×9/(26.98×4+6.94×9) = 36.7%)



Homework 3

Based on the Al-Mg phase diagram:

1. What are the melting point for pure Al and pure Mg?
2. For an Al-Mg alloy with 10 wt.% Mg
   a. At what temperature does solid first form and what is its composition?
   b. At 550°C, what are the phases present, under equilibrium? What is their composition or chemistry? What is the relative amount or weight fraction for each phase?
   c. At what temperature does last liquid disappear? What is its composition
   d. What about answers for b, but at 400°C?
   e. What about answers for b, but at 100°C?



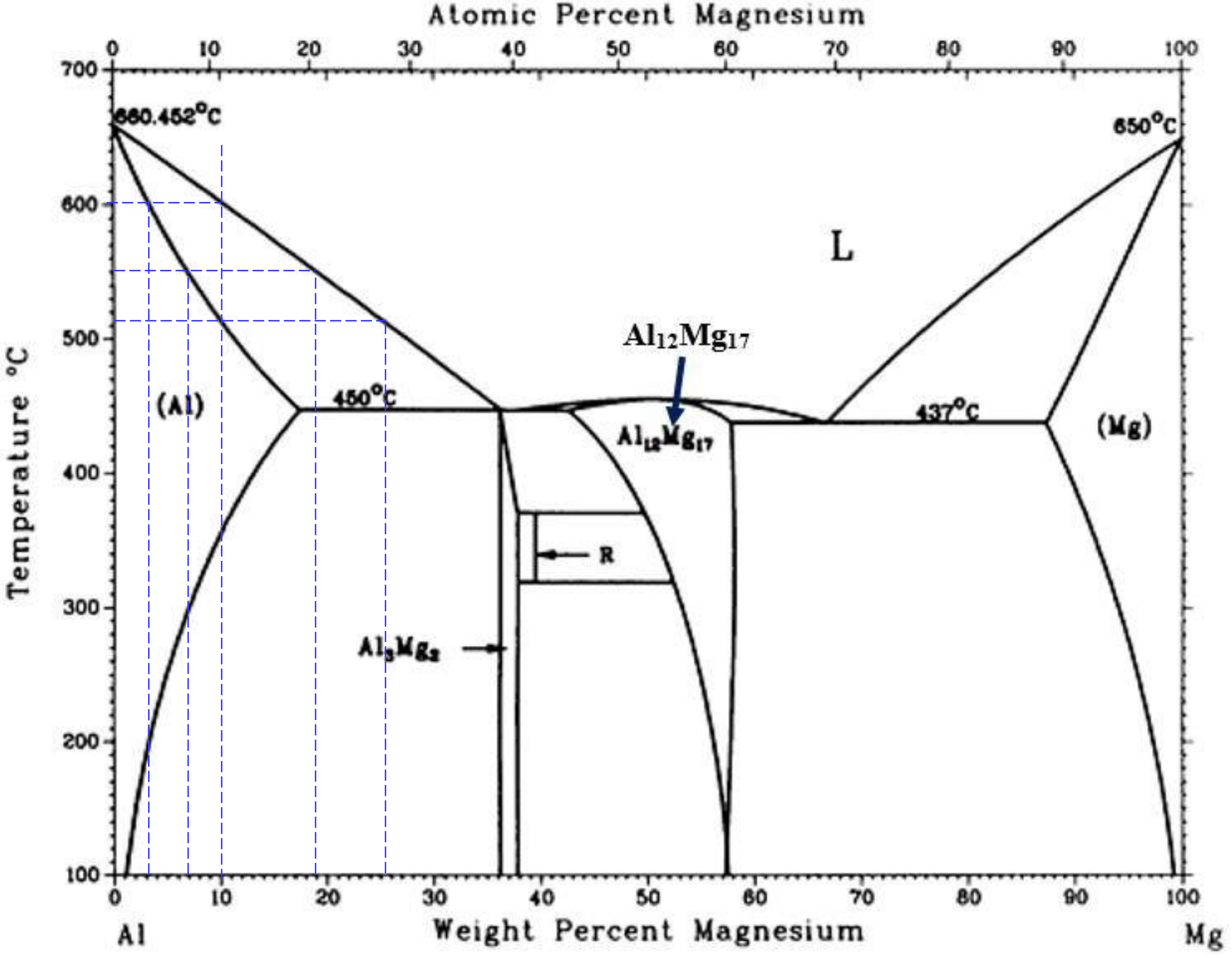
Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

Homework 3

1. Melting point:
   T_m (Al) = 660°C; T_m (Mg) = 650°C
2. For Al-Mg alloy w/ 10 wt.% Mg
   a. Solid first forms at ~600°C,
      its composition ~3 wt.% Mg

   b. At 550°C, two phases present -
      (Al) solid solution and liquid;
      Composition for each phase:
      $C_{(Al)} \approx 7$ wt.% Mg
      $C_L \approx 19$ wt.% Mg
      Weight fraction for each phase:
      $w_{(Al)} \approx ?/?? = 75$ wt.%
      $w_L \approx ?/?? = 25$ wt.%

   c. Last liquid disappears at ~510°C;
      its composition ~25.5 wt.% Mg

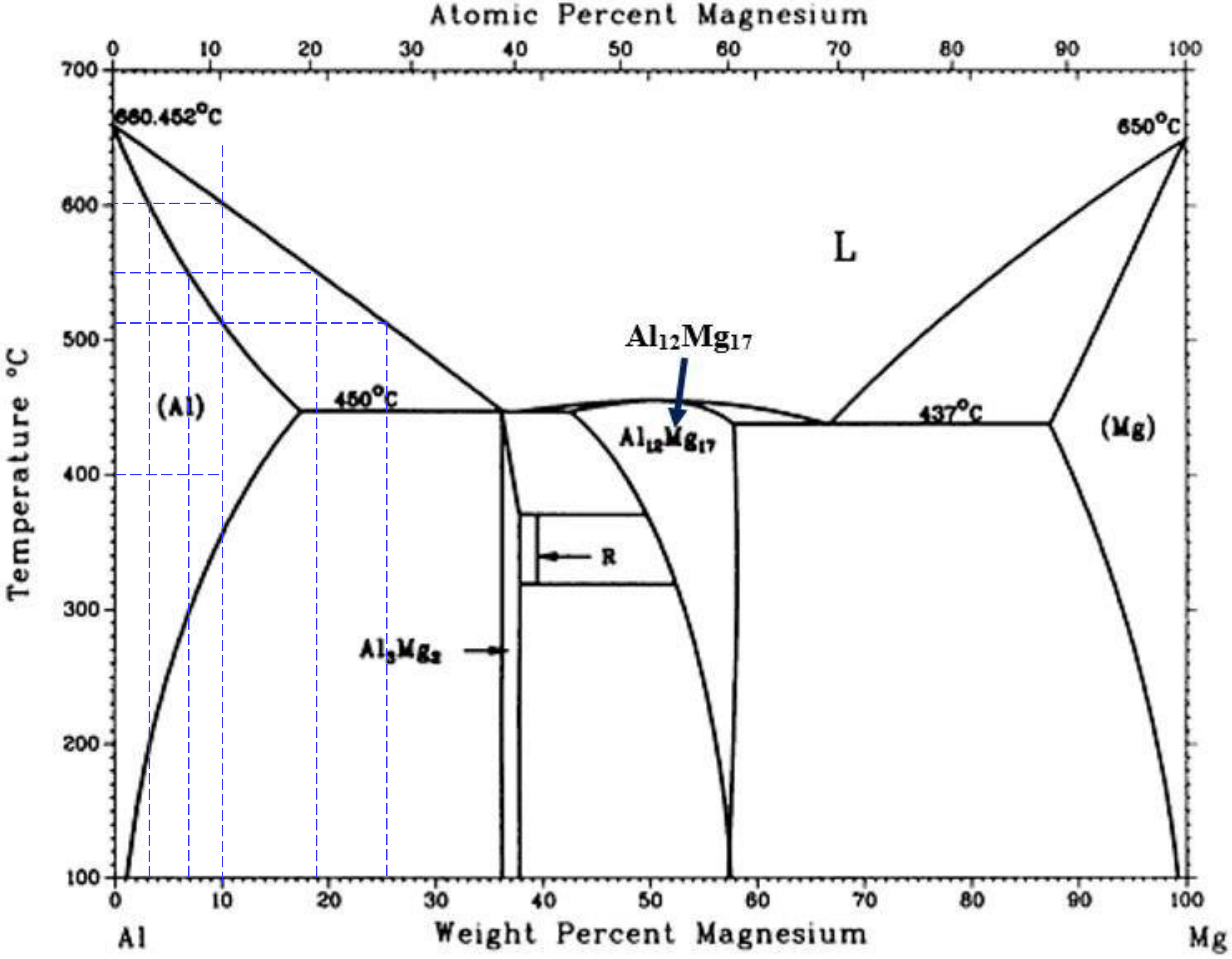


Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

Homework 3

2. For Al-Mg alloy w/ 10 wt.% Mg
   d. At 400°C, single phase present:
      (Al) solid solution;
      Composition for (Al) s.s.:
      $C_{(Al)} \approx 10$ wt.% Mg
      Weight fraction for (Al) s.s.:
      $w_{(Al)} = 100$ wt.%

   e. At 100°C, two phases present - (Al) solid solution and Al_3Mg_2
      Composition for each phase
      $C_{(Al)} \approx 1$ wt.% Mg
      $C_{Al3Mg2} \approx 36$ wt.% Mg
      (Theoretical value:
      24.30×2/(24.30×2 + 26.98×3) = 37.5 wt% Mg,
      meaning slightly Mg deficient or Al rich)
      Weight fraction for each phase:
      $w_{(Al)} = ?/?? = 74.3$ wt.%
      $w_{Al3Mg2} = 1 - w_{(Al)} = 25.7$ wt.%

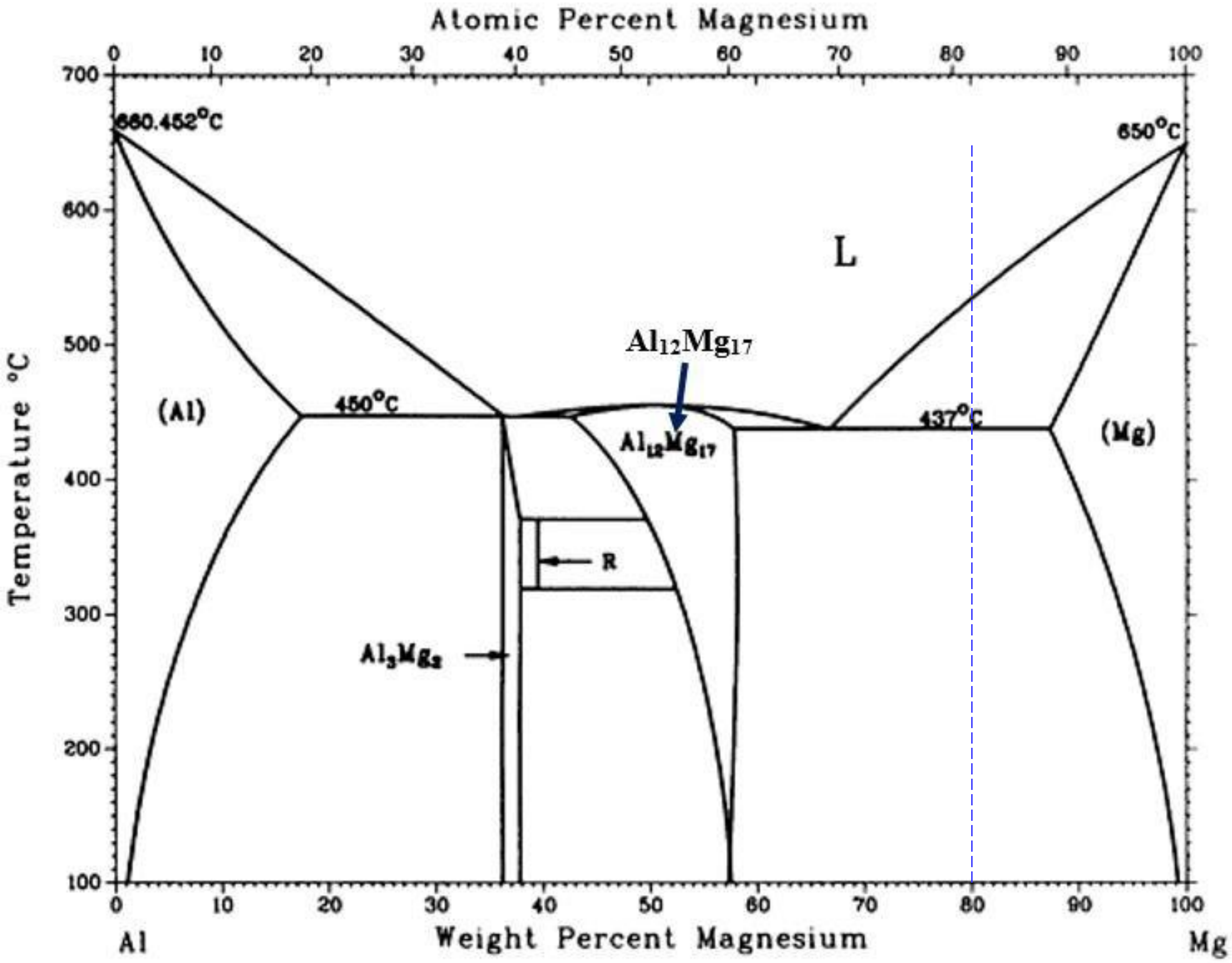


Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

Homework 4

Based on the Al-Mg phase diagram:

1. For an Al-Mg alloy with 80 wt.% Mg
   a. At 440°C (just above eutectic temperature, what are the phases present, under equilibrium? What is their composition or chemistry? What is the relative amount or weight fraction for each phase? Please also roughly illustrate the microstructure
   b. What about answers for a, but at 435°C (just below eutectic temperature)? Please also roughly illustrate the microstructure



Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

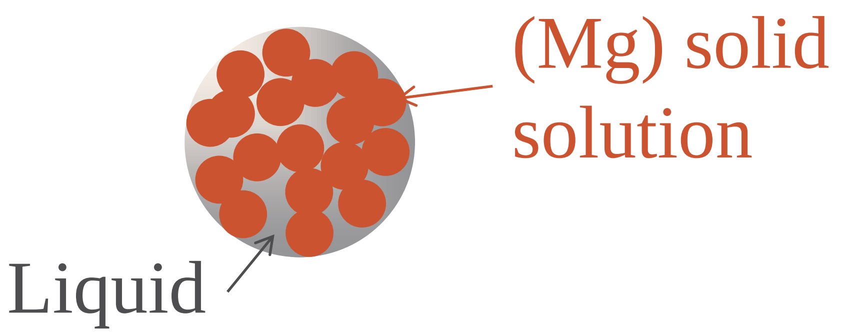
Homework 4

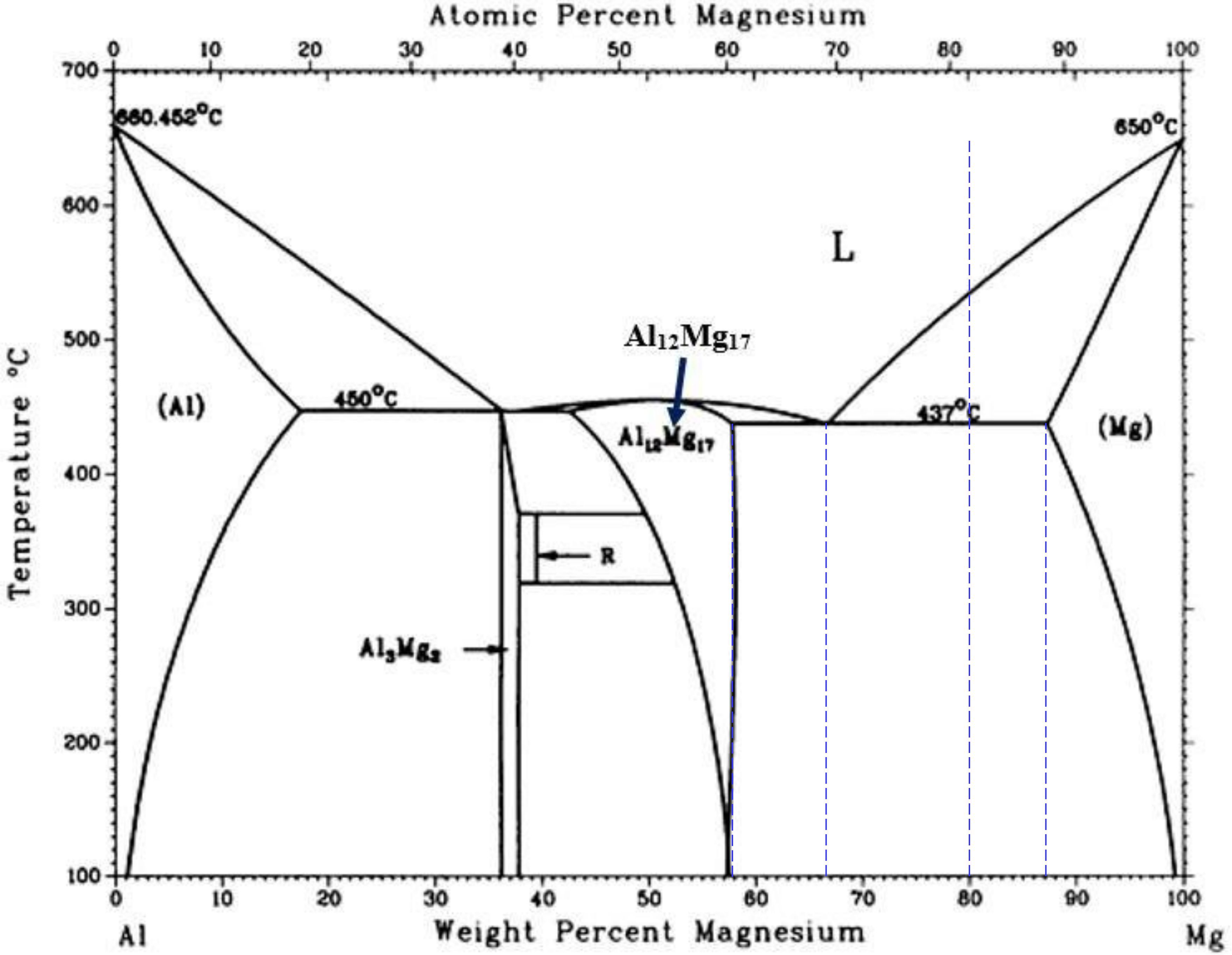
1. For Al-Mg alloy w/ 80 wt.% Mg
   a. At 440°C (just above eutectic temperature), two phases present - L and (Mg) solid solution

      Composition for each phase:
      $C_L \approx 67$ wt.% Mg
      $C_{(Mg)} \approx 87$ wt.% Mg

      Weight fraction for each phase
      w_L = ?/?? = 35 wt.%
      $w_{(Mg)}$ = ??? = 65 wt.%

      Schematic for microstructure:





Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

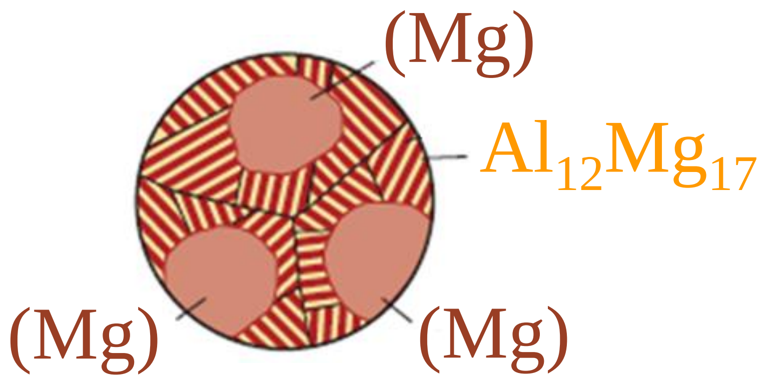
Homework 4

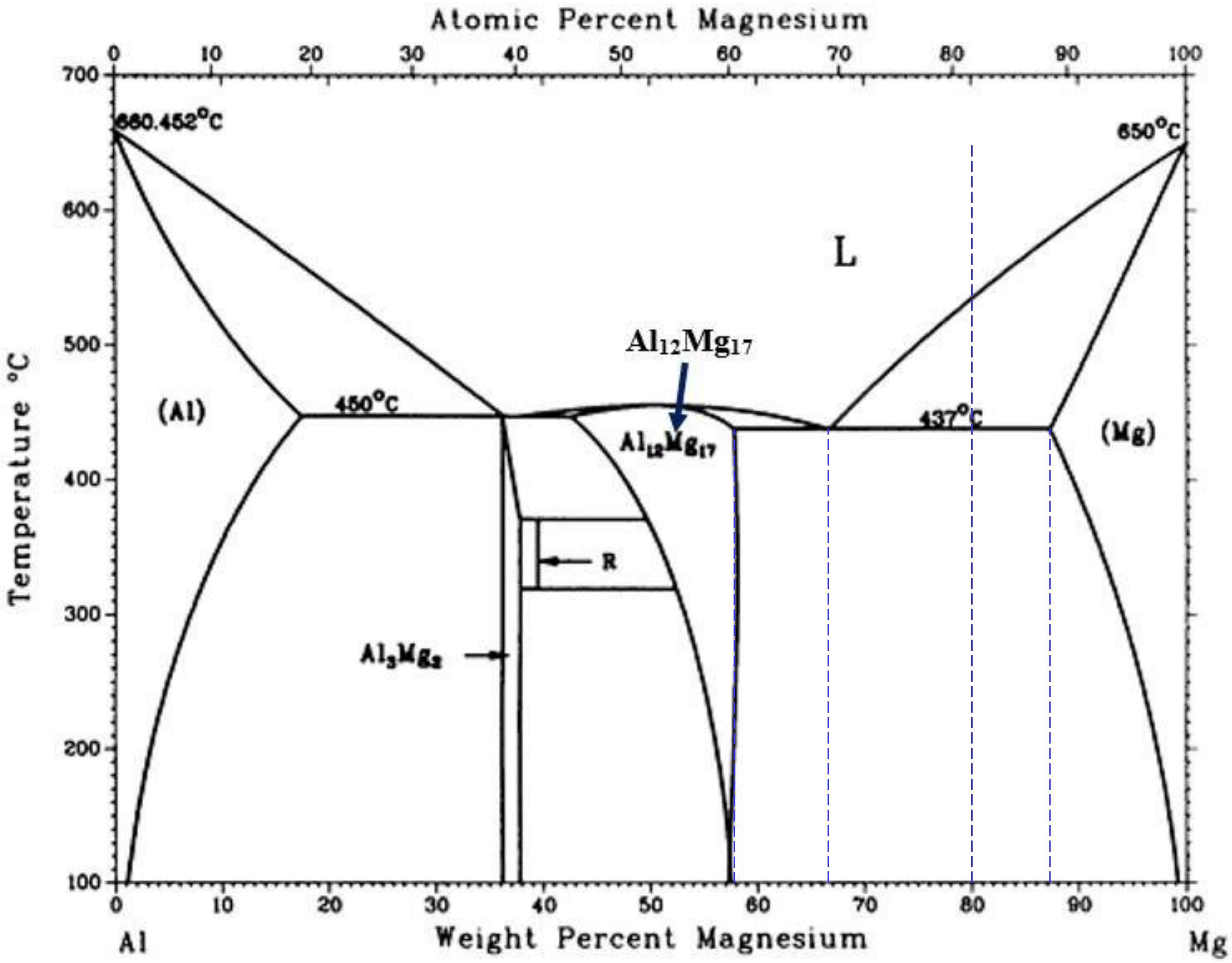
1. For Al-Mg alloy w/ 80 wt.% Mg
   b. At 435°C (just below eutectic temperature), two phases present - $Al_{12}Mg_{17}$ and (Mg), both solid solution

   Composition for each phase:
   $C_{Al12Mg17} \approx$ 58 wt.% Mg
   $C_{(Mg)} \approx$ 87 wt.% Mg

   Weight fraction for each phase
   $w_{Al12Mg17}$ = ?/?? = 24 wt.%
   $w_{(Mg)}$ = ??? = 76 wt.%

   Schematic for microstructure:



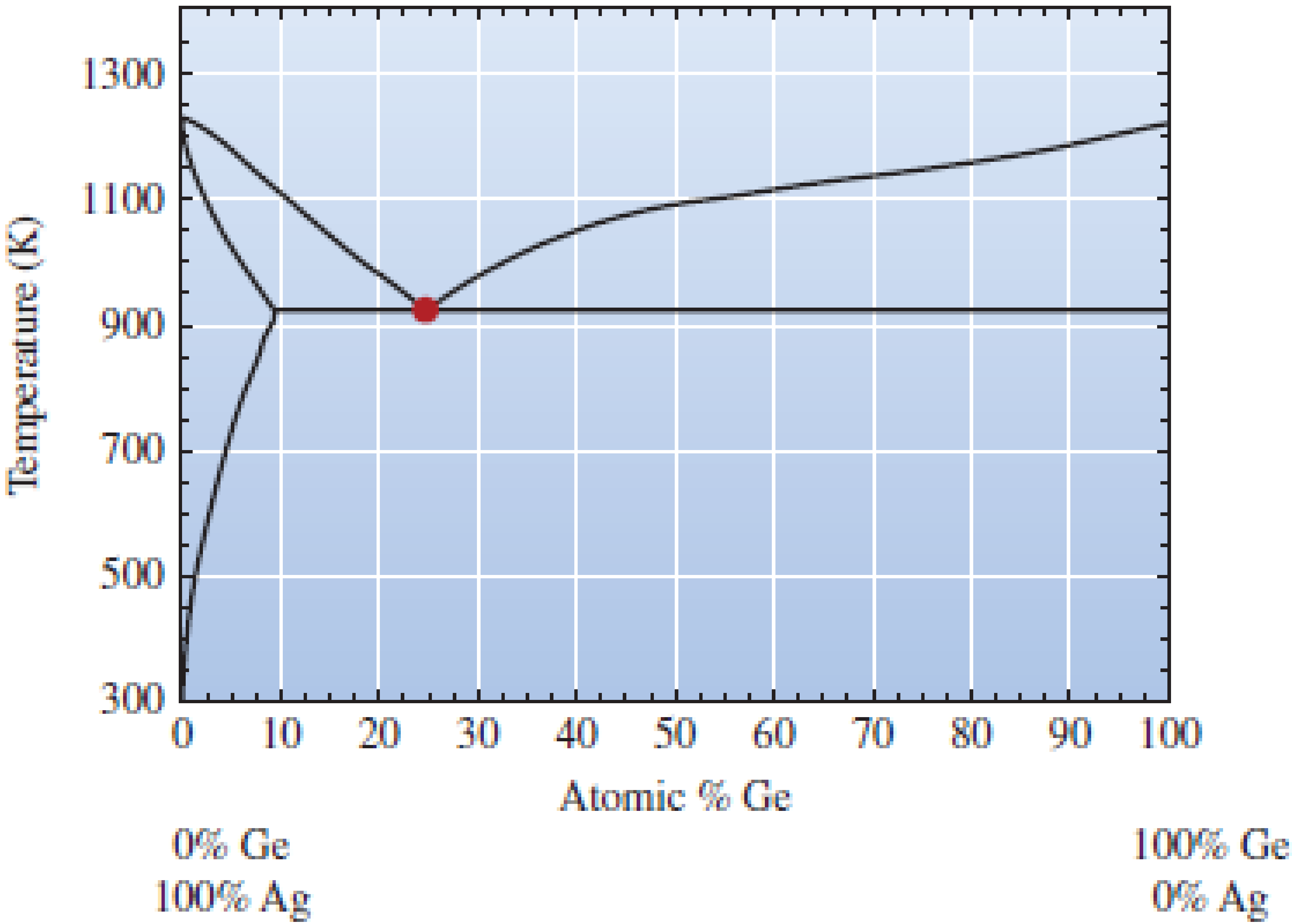


Remember between two (neighboring) single-phase regions/line, there would be a two-phase region

Homework 5

Based on the phase diagram for the Ag-Ge system, roughly draw the cooling curves and indicate the appropriate temperatures, for the following Ag-Ge alloys:

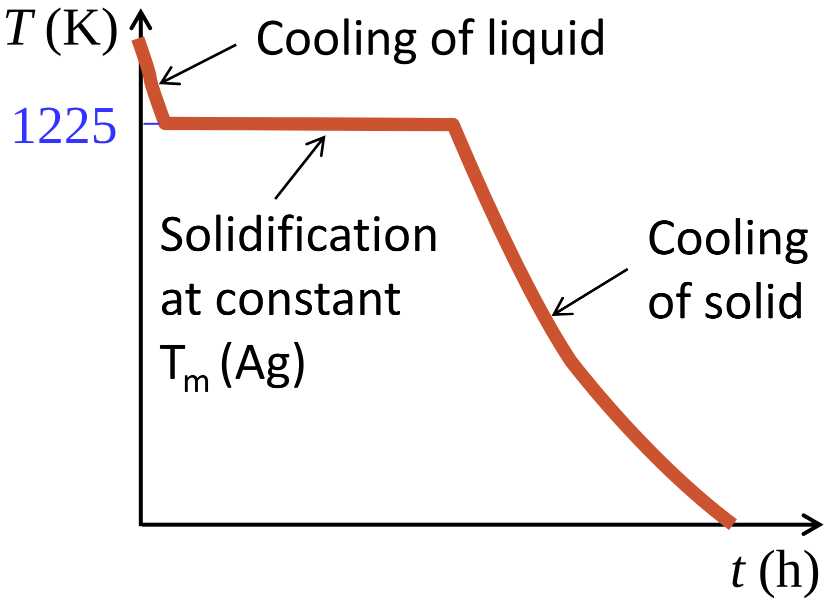
1. 100 at.% Ag
2. 95 at.%Ag-5 at.% Ge
3. 85 at.% Ag-15 at.% Ge
4. 75 at.% Ag-25 at.% Ge
5. 55 at.% Ag-45 at.% Ge
6. 100 at.% Ge



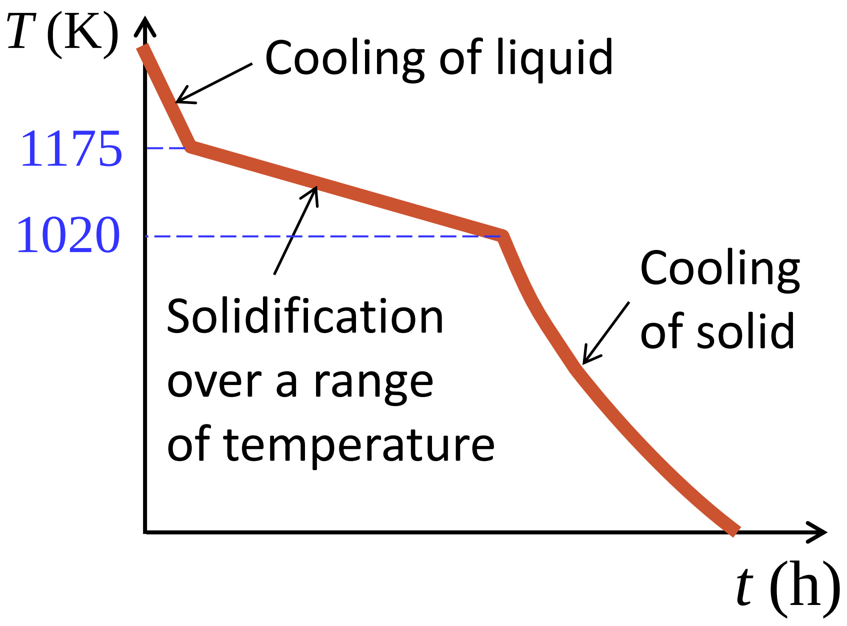
Homework 5

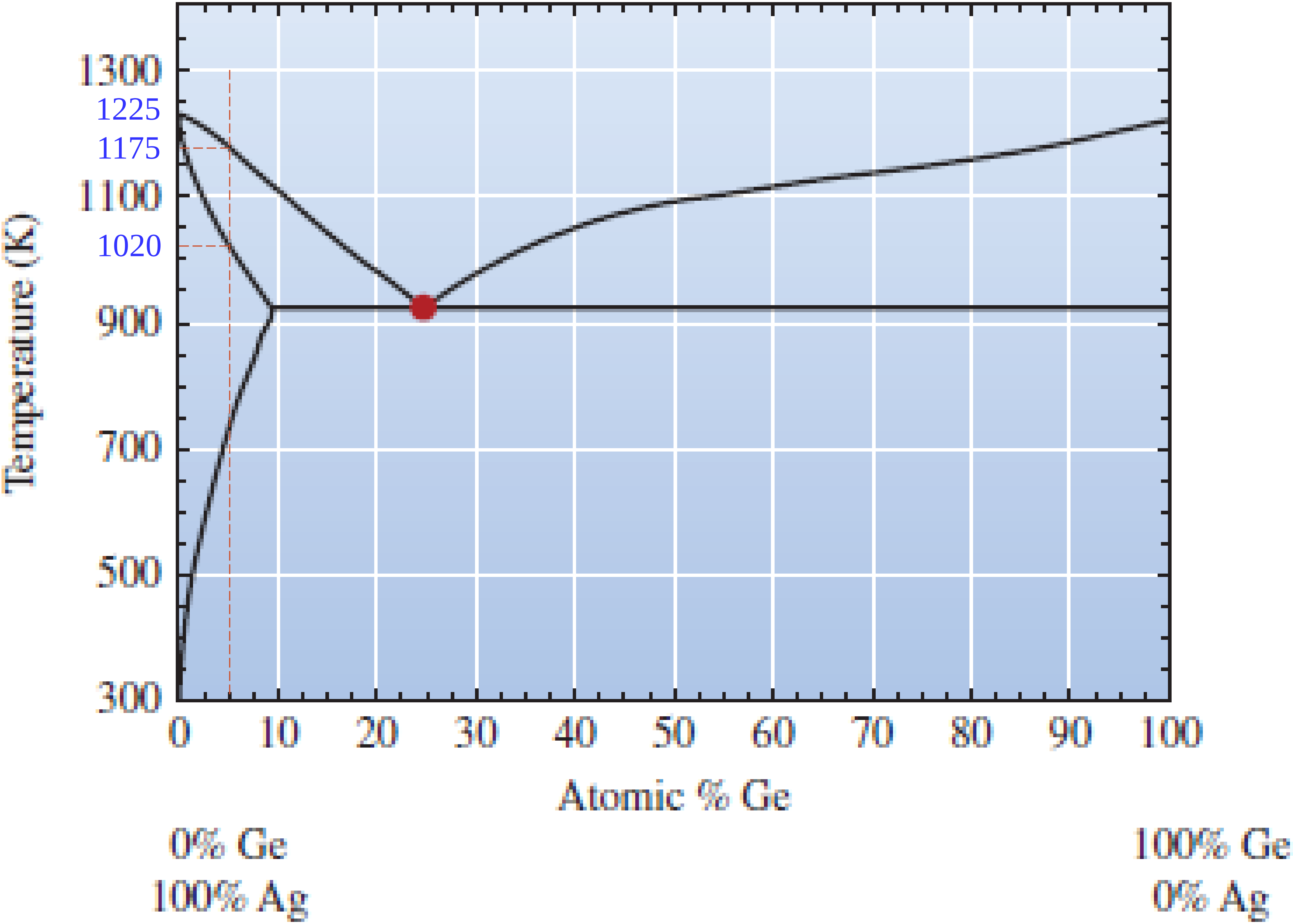
Cooling curves:

1. 100 at.% Ag



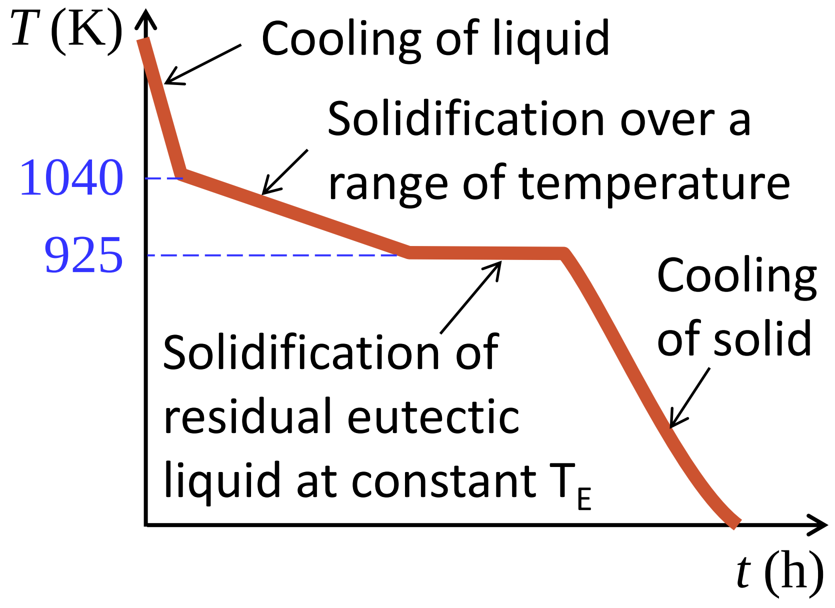
2. 95 at.%Ag-5 at.% Ge



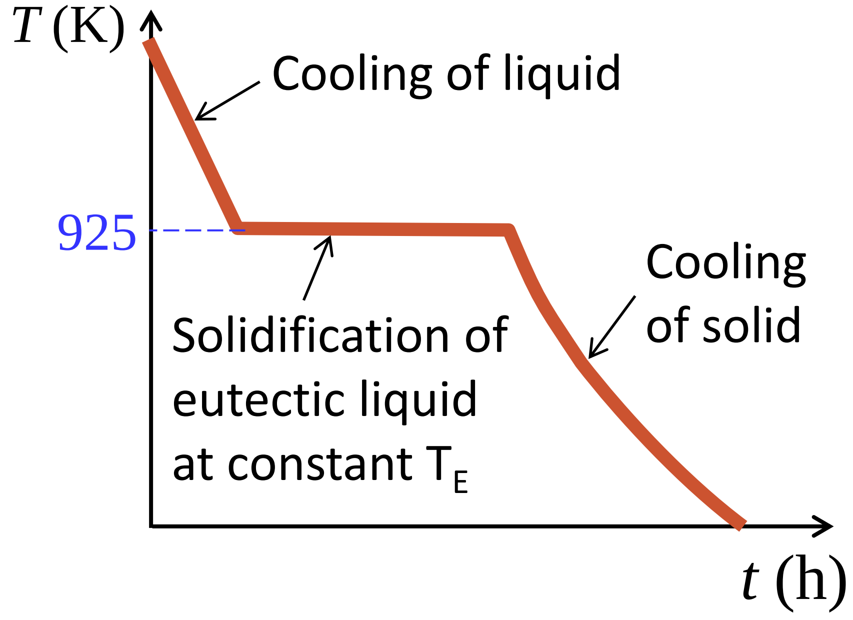


Cooling curves:

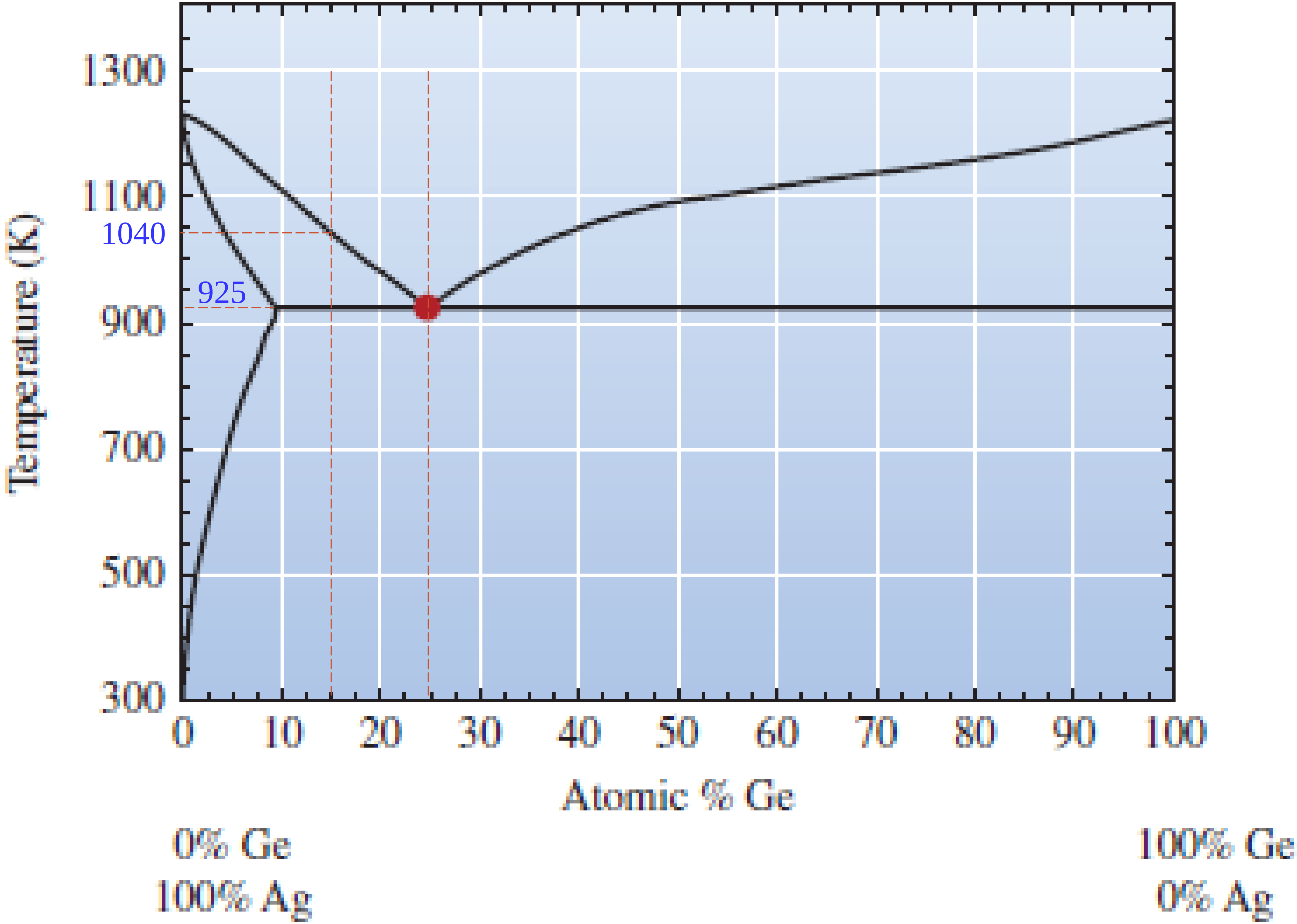
3. 85 at.% Ag-15 at.% Ge



4. 75 at.% Ag-25 at.% Ge

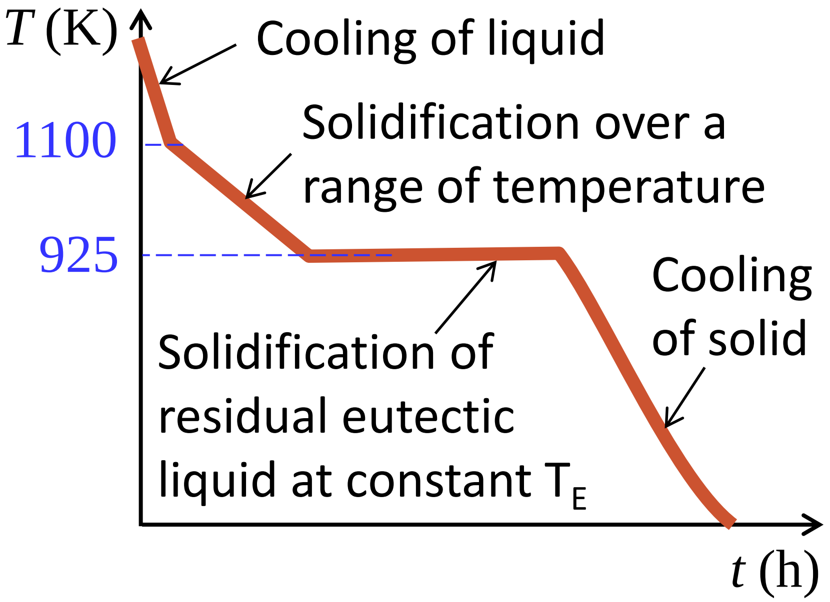


Homework 5

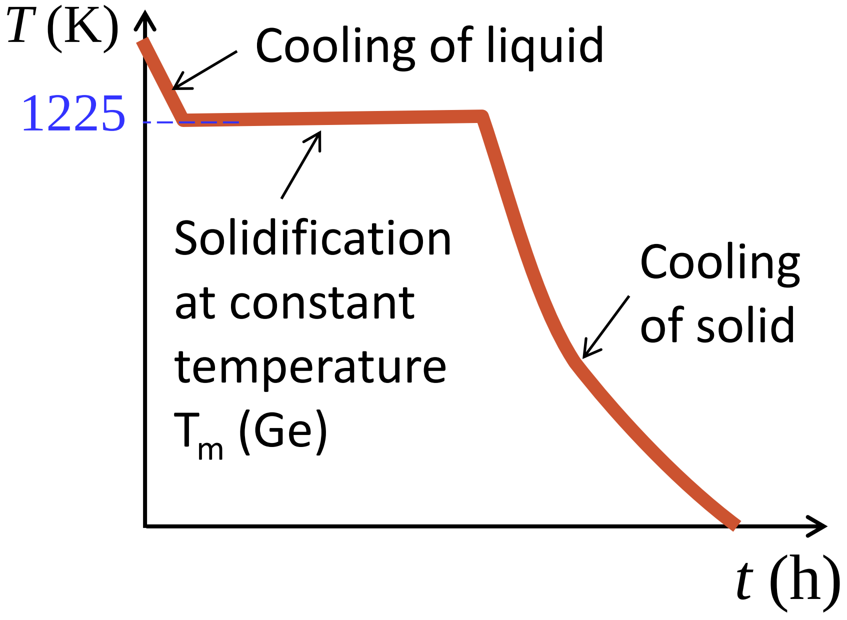


Cooling curves:

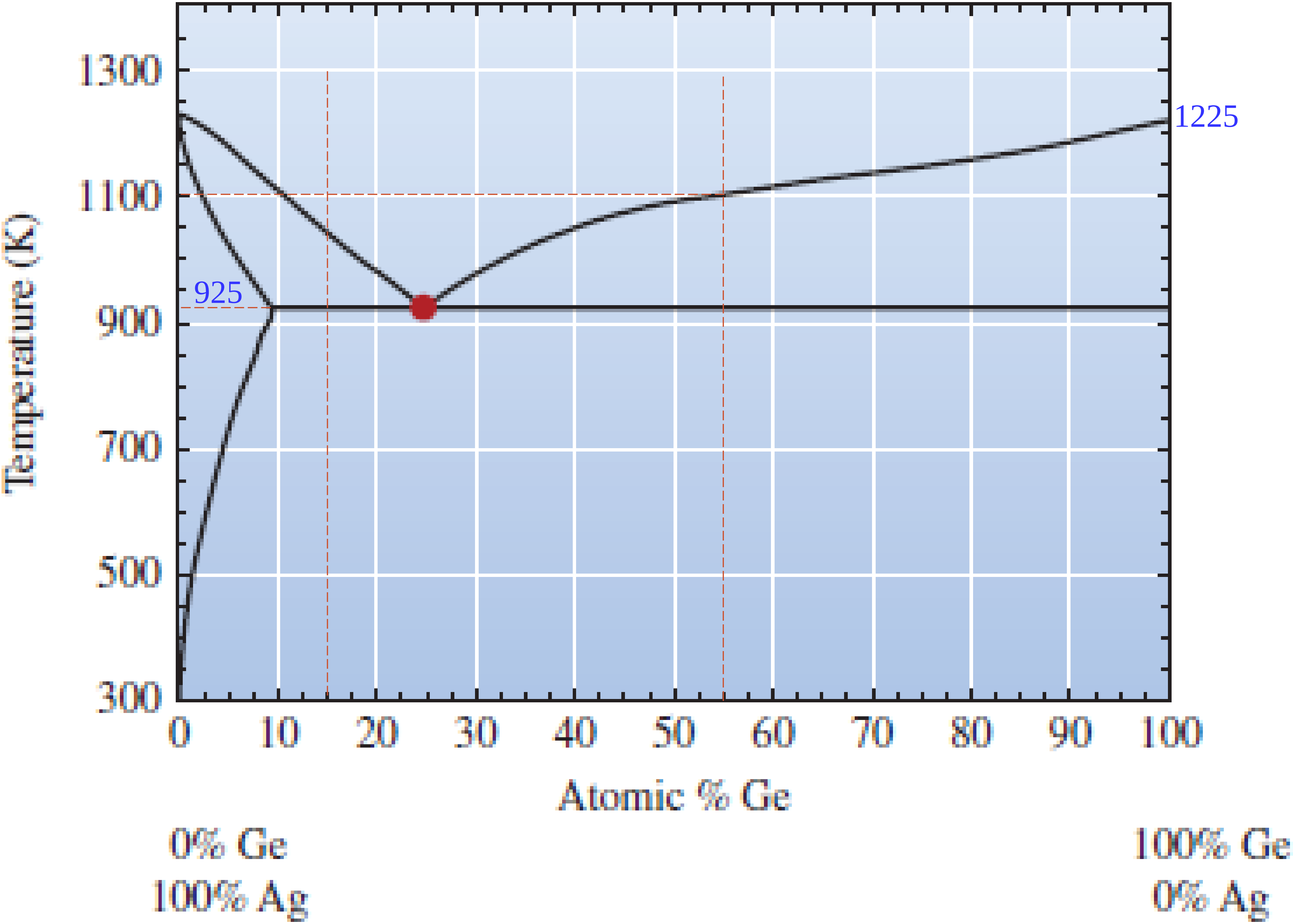
5. 55 at.% Ag-45 at.% Ge



6. 100 at.% Ge

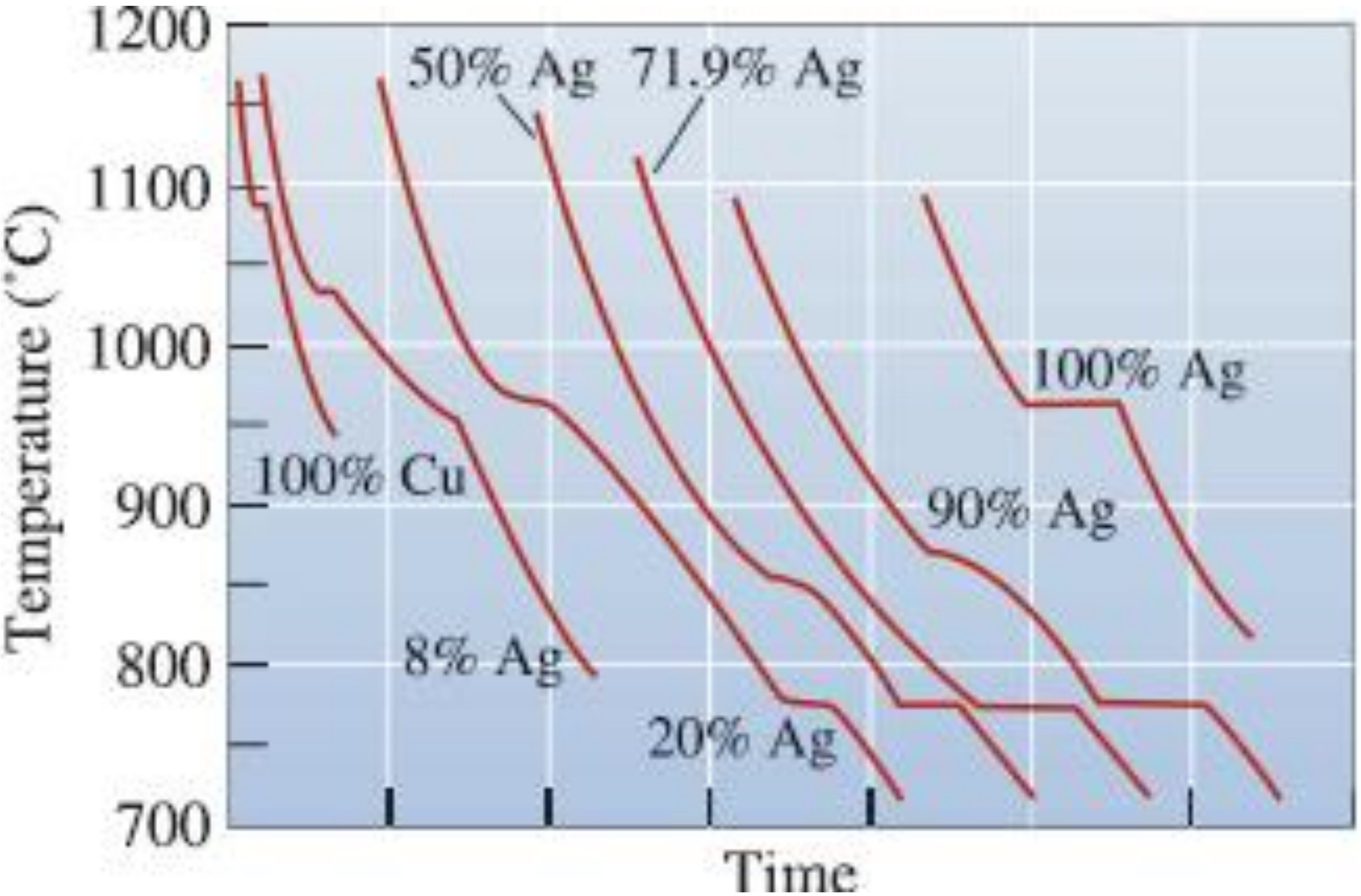


Homework 5



Homework 6

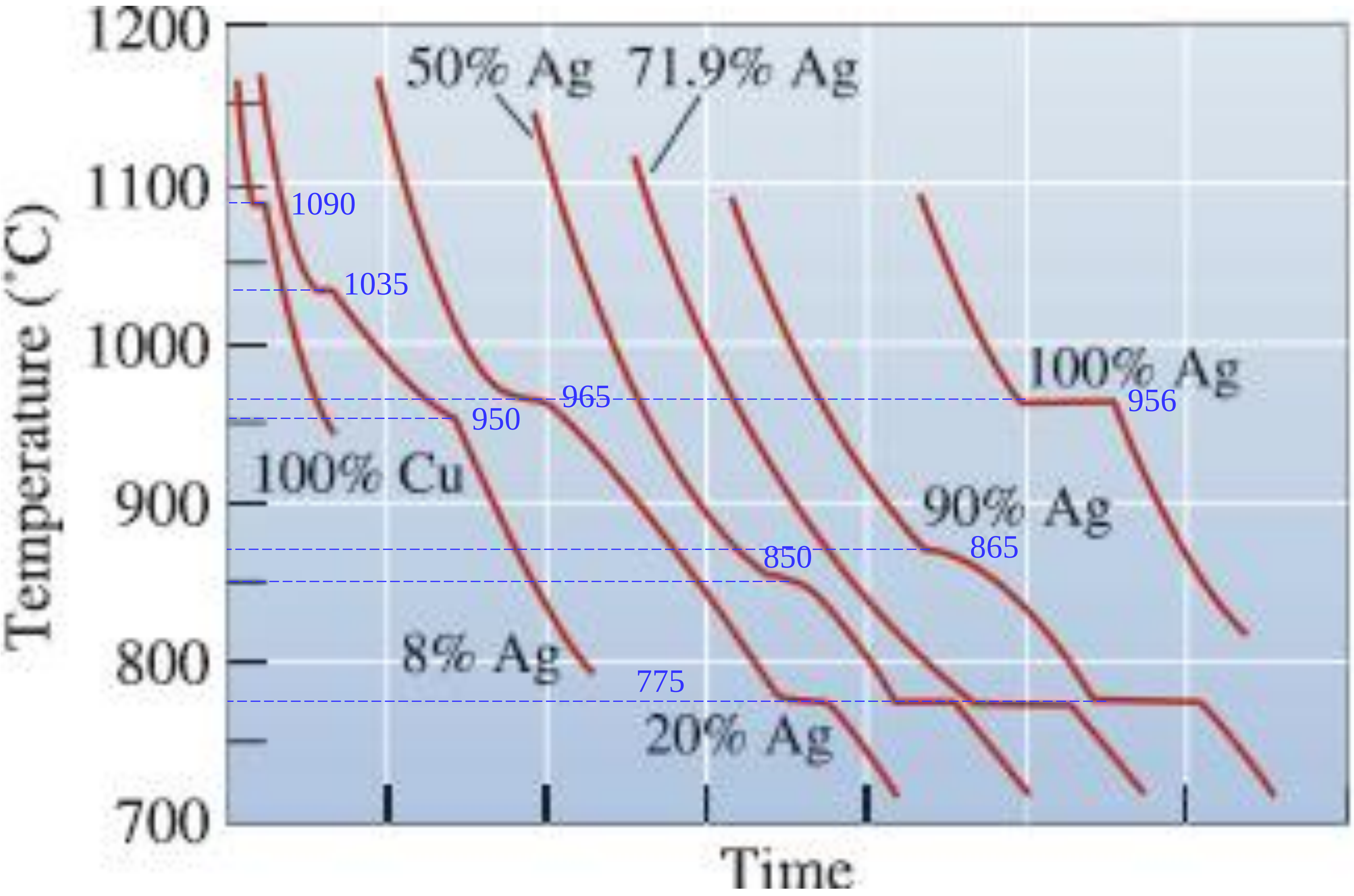
Based on the series of cooling curves, please roughly re-construct the phase diagram. Note the max solubility for Ag in Cu is 7.9 wt.%, while the max solubility of Cu in Ag is 8.8 wt.%. Please be sure to explain your work and label the relevant points



Homework 6

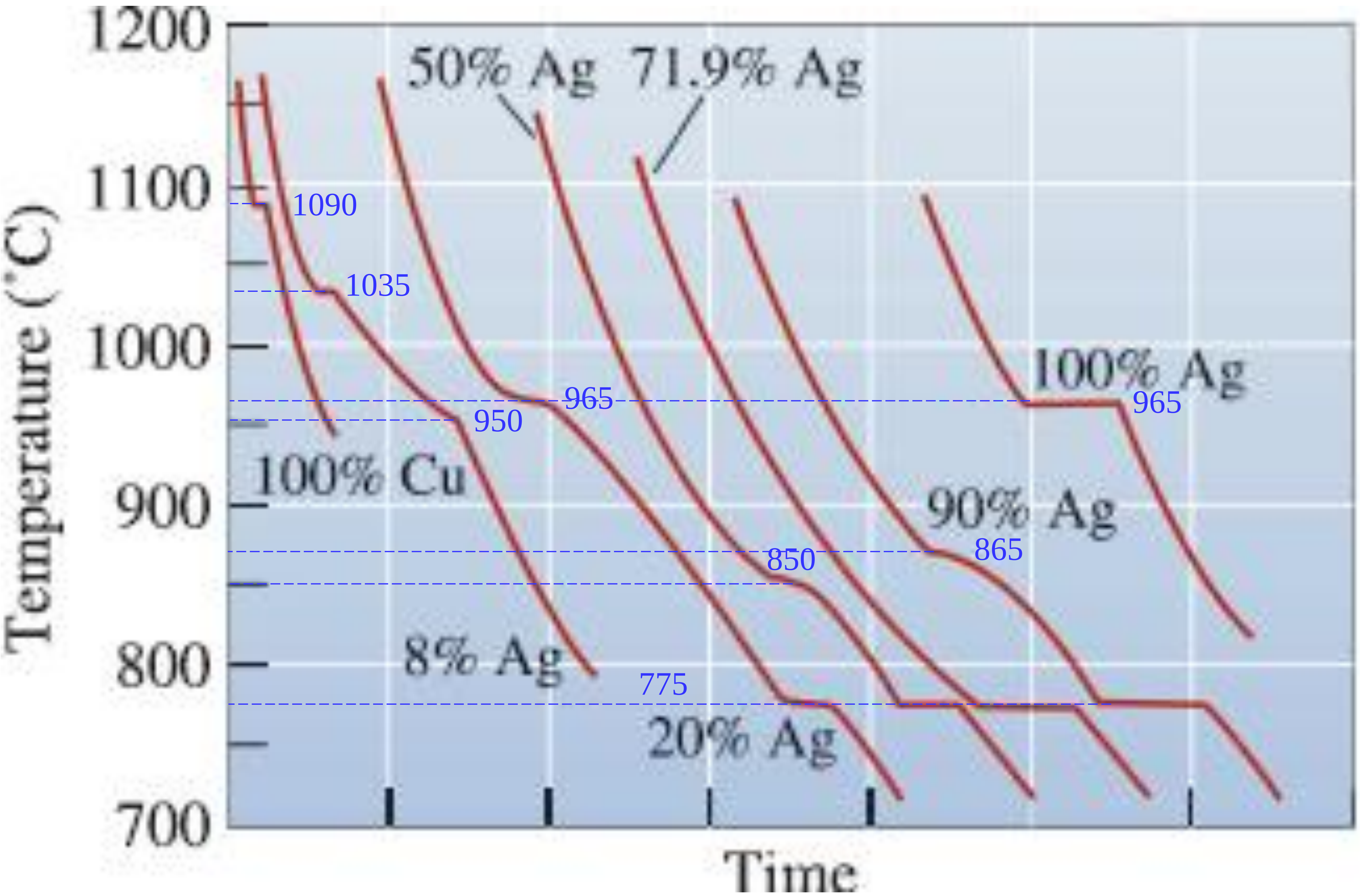
From different cooling curves, critical points on the Cu – Ag phase diagram are obtained:

- 100% Cu:
  T_m (Cu) = 1090^{o}C
- 8% Ag:
  solid starts to form at
  $T_{Liquidus} \approx 1035^oC$
  liquid disappears at
  $T_{solidus} \approx 950^oC$
- 20% Ag (hypoeutectic):
  $T_{Liquidus} \approx 965^oC$
  Eutectic temperature:
  $T_E \approx 775^oC$

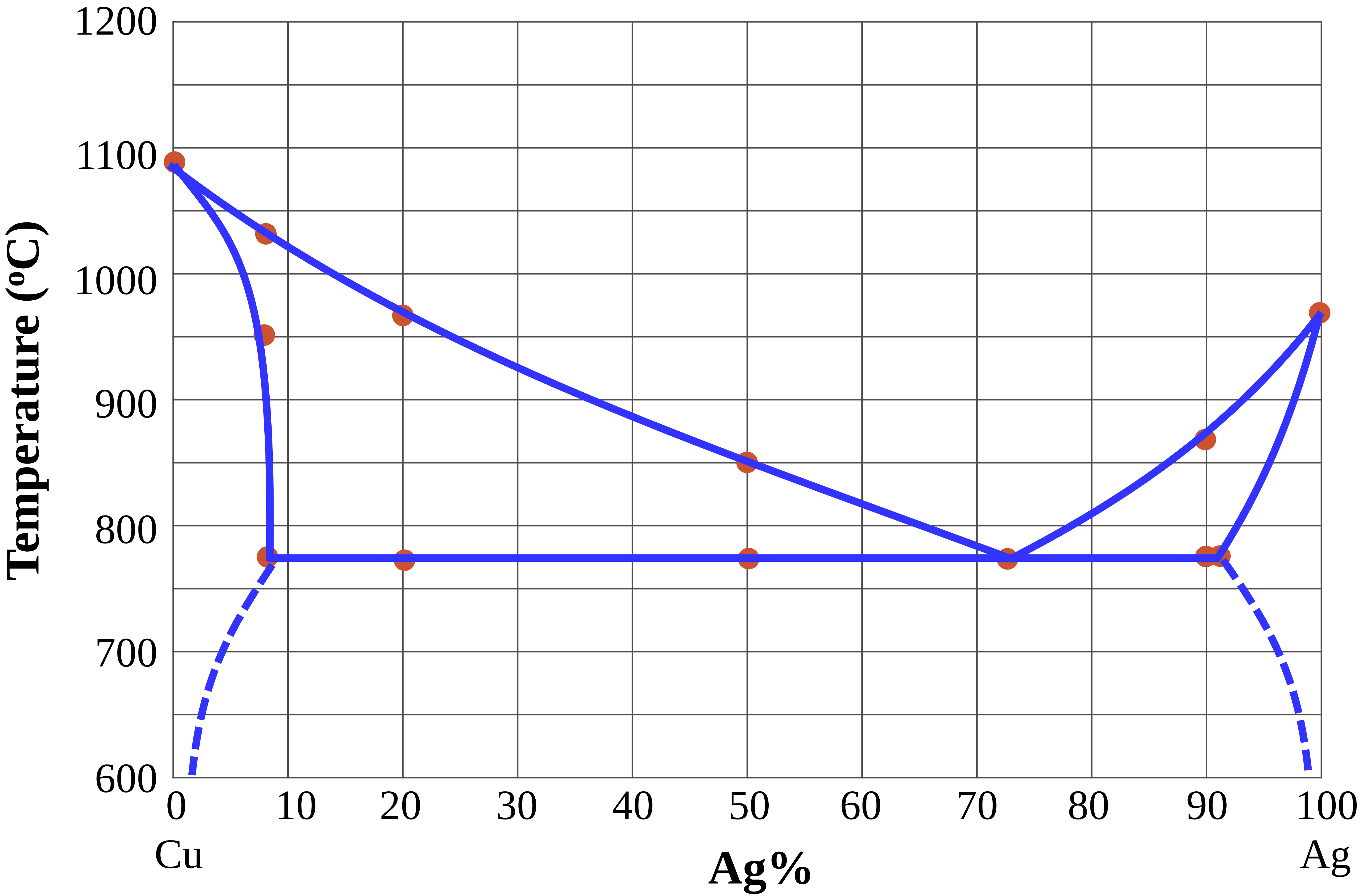


Homework 6

- 50% Ag (hypoeutectic):
  $T_{Liquidus} \approx 850^oC$
  $T_E \approx 775^oC$
- Eutectic temperature
  $T_E \approx 775^oC$
  $C_L = 71.9\%$ Ag
  $C_{(Cu)} = 7.9\%$ Ag
  $C_{(Ag)}$=1-8.8% = 91.2% Ag
- 90% Ag (hypereutectic):
  $T_{Liquidus} \approx 865^oC$
  $T_E \approx 775^oC$
- 100% Ag:
  T_m (Ag) = 965^oC



Homework 6



1200
1100
1000
900
800
700
600
Temperature (ºC)
0
10
20
30
40
50
60
70
80
90
100
Cu
Ag
Ag%

Homework 7

For carbon steel w/ 1 wt.% C on slow (**<u>equilibrium)</u>** cooling, determine:

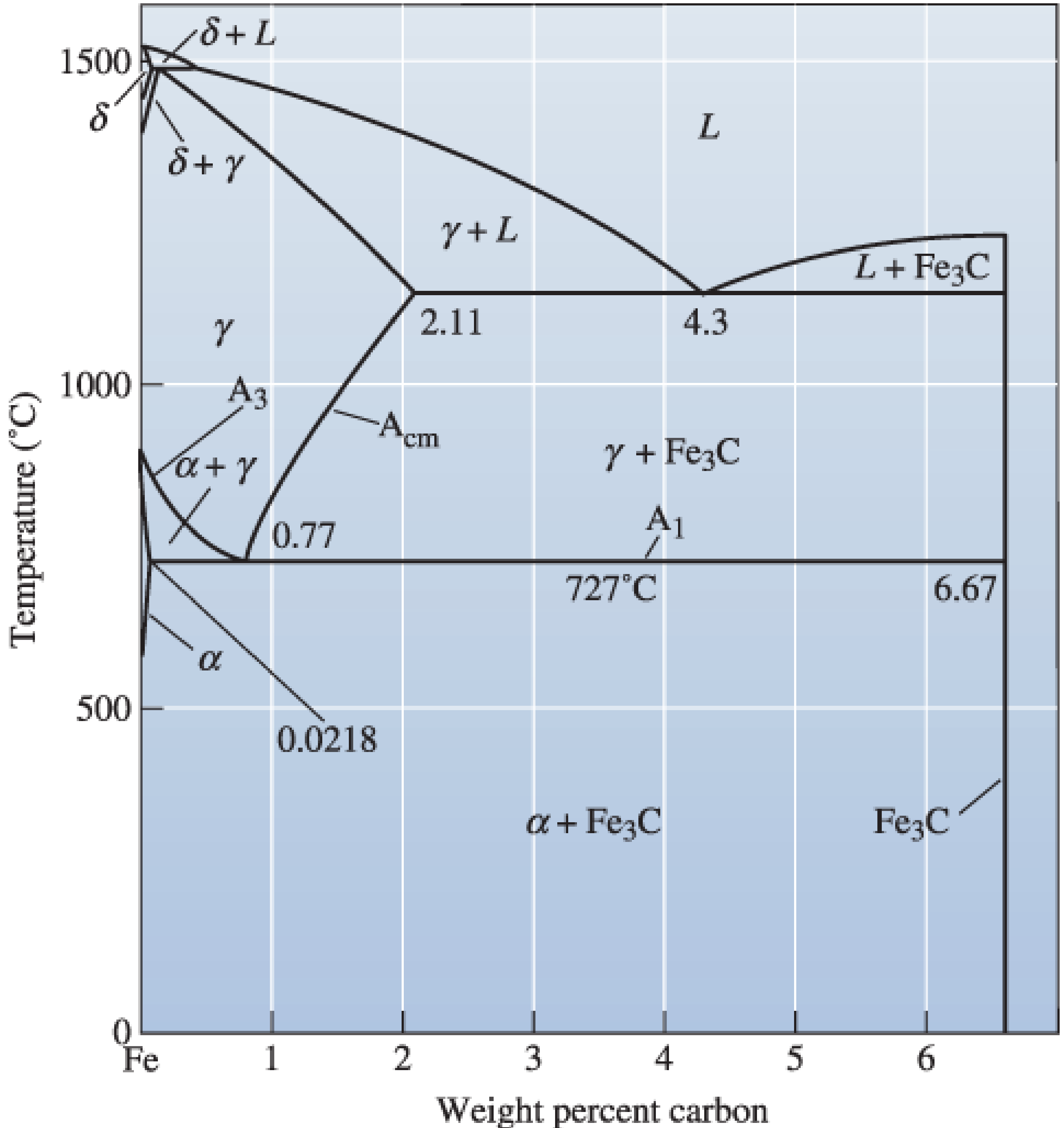
(a) The temperature when the γ phase (called austenite) start to first transform to other phases?

(b) The composition/chemistry and relative amount of each phase present at 730°C

(c) The composition/chemistry and relative amount of each phase present at 725°C

(d) If the primary Fe_3C (i.e., **Fe_3C** formed above eutectoid temperature) is treated as a **microconstituent**, while the **eutectoid Fe/Fe_3C lamellar** is regarded as **another microconstituent**, what the is composition and relative amount for each of the two micro-constituents?

(e) Draw microstructure for (b) and (c)

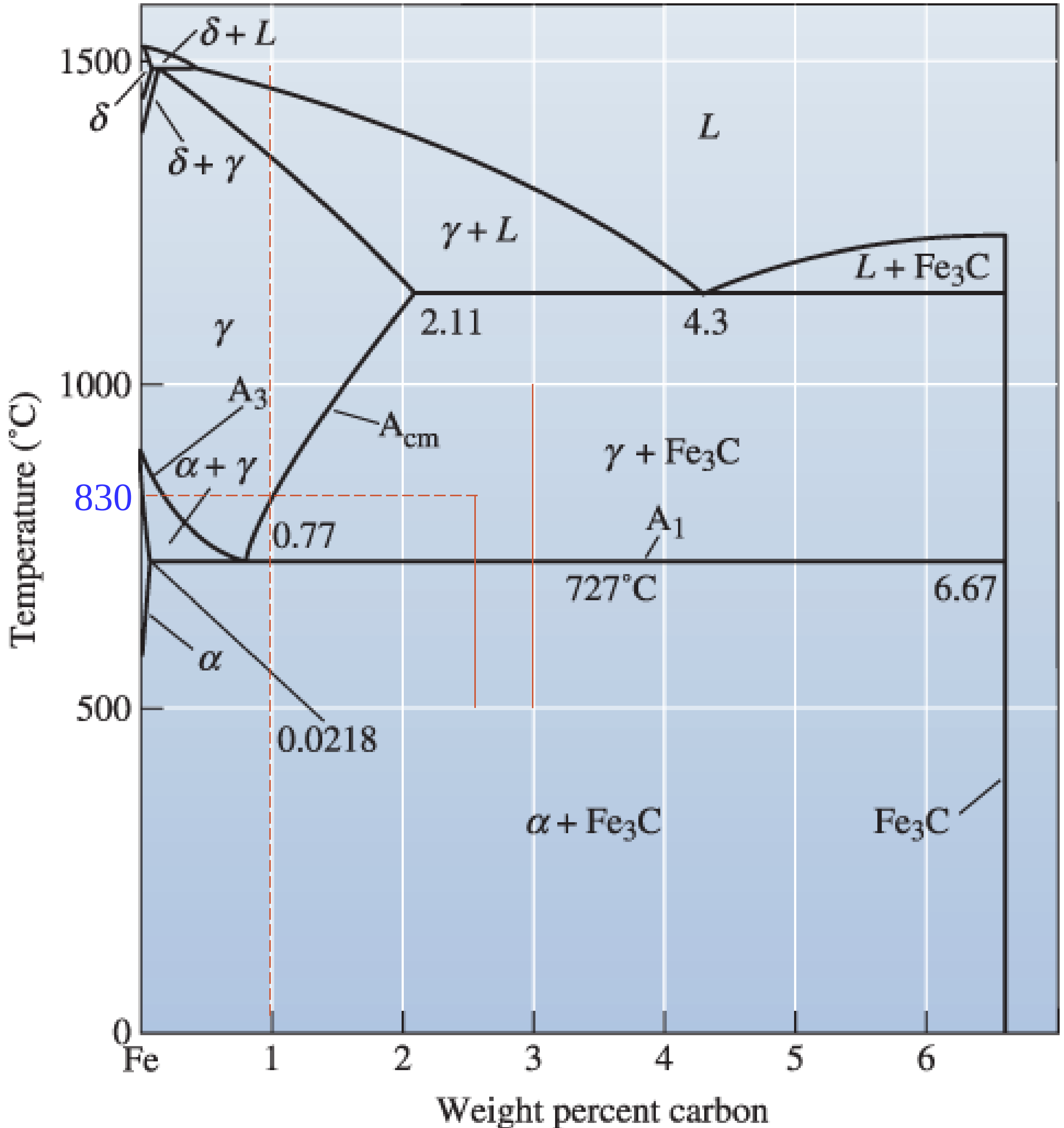


Homework 7

For carbon steel w/ 1 wt.% C on slow cooling:
(a) The temperature when the γ phase starts to first transform to other phases (Fe3C precipitate) is **~830ºC** (~100ºC higher than eutectoid temp)

(b) At 730ºC, two phases: γ and Fe_3C:
Composition for each phase:
C_γ = 0.77 wt.% C
C_{Fe3C} = 6.67 wt.% C
Relative amount for each phase
w_γ = (6.67-1)/(6.67-0.77) = 96 wt.%
w_{Fe3C} = 1 – 96wt.% = 4 wt.%

(c) At 725ºC, two phases: α and Fe_3C:
Composition for each phase:
C_α = 0.0218 wt.% C
C_{Fe3C} = 6.67 wt.% C
Relative amount for each phase
w_α = (6.67-1)/(6.67-0.0218) = 85 wt.%
w_{Fe3C} = 1 – 85wt.% = 15 wt.%



Homework 7

For carbon steel w/ 1 wt.% C on slow cooling:

(d) If the primary Fe_3C (i.e., $\mathbf{Fe_3C}$ formed above eutectoid temperature) is treated as a **microconstituent**, while the **eutectoid Fe/**$\mathbf{Fe_3C}$ **lamellar** is regarded as **another microconstituent**, composition for each microconstituent:

C(primary Fe_3C) = 6.67 wt.% C

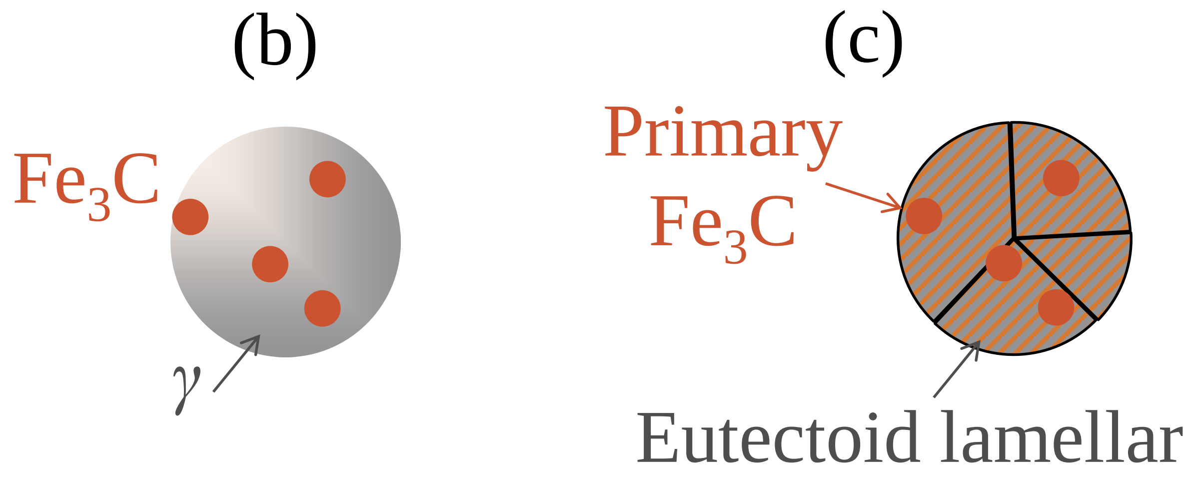
C(eutectoid lamellar) = 0.77 wt.% C

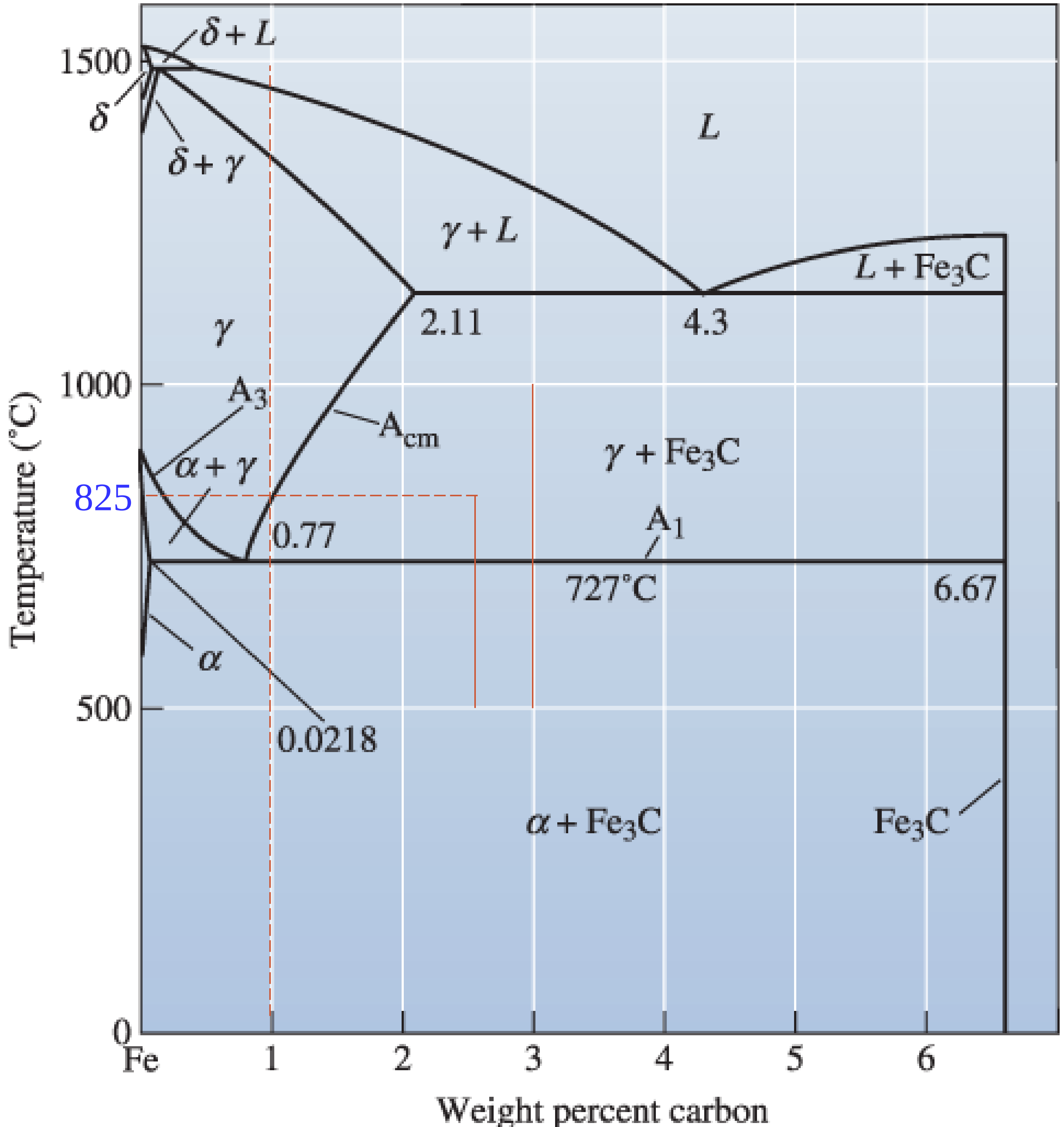
Relative amount for each microconstituent:

$w_{\text{primary Fe3C}}$ = (1-0.77)/(6.67-0.77) = 4 wt.%

$w_{\text{eutectoid lamellar}}$ = 1 – 4 wt.% = 96 wt.%

(e) Microstructure schematics:





Homework 8

Based on the partial phase diagram for the ZrO_2-CaO system, determine the eutectoid temperature and the composition for each of the phase involved in the eutectoid phase transformation

Eutectoid temperature: ~875^{o}C
If ZrO_2-CaO for short as *CSZ*
Eutectoid reaction/transformation:

tetragonal-CSZ = *monoclinic*-CSZ + *cubic*-CSZ

Composition for each phase involved:
C(*tetragonal*-CSZ) ≈ 13 wt.% CaO
C(*monoclinic*-CSZ) ≈ 3 wt.% CaO
C(*monocubic*-CSZ) ≈ 16 wt.% CaO