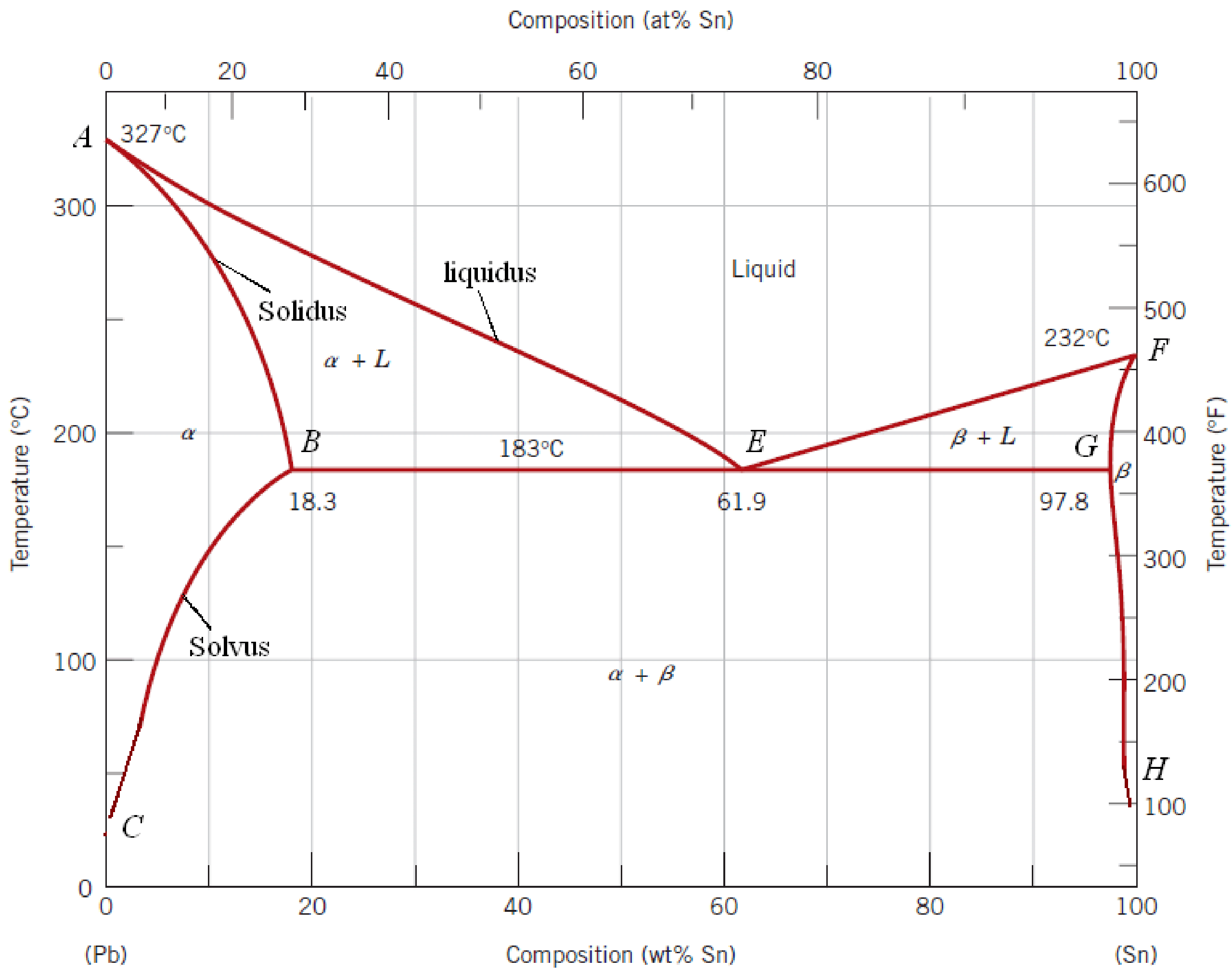
1

To the right you are given the phase diagram for the Pb-Sn system (binary eutectic). Say we have a 30 wt% Sn – 70 wt% Pb alloy that is gradually cooled from 300°C to 50°C.



a

Is this a hypreutectic or hypoeutectic alloy?

✓ **Answer** ⌄

hypoeutectic, as the composition is left of the eutectic composition.

b

Describe the microstructure that would develop during cooling (can use pictures, but be sure that everything is legible and clearly labeled). Be sure to specify **both** the *phases* and *microconstituents* present.

✓ Answer

While the mixture is from 300-250°C, it is all homogenously liquid.
While cooling from 250°C to the eutectic isotherm, solid alpha particles form in the liquid
Once it cools below the eutectic isotherm, alternating layers of alpha and beta will form around the alpha particles as well, all microconstituents are solid now.

c

What is the composition (in wt% Sn) of each of the microconstituents present after cooling?

✓ Answer

Both the primary and eutectic alpha have a Sn composition of 18.3%, while the eutectic beta has a composition of 97.8% Sn.

d

How is the resulting microstructure different from what would be developed if the same cooling regime was applied to a 10 wt% Sn - 90 wt% Pb alloy?

✓ Answer

While cooling, it passes through an alpha only phase, which means that the alpha has solidified, trapping liquid beta within it. The liquid beta then only cools once it reaches the alpha+beta phase. This means that the structure will look mainly alpha with small beta patches within each alpha particle.

2

Find a research paper that uses phase diagrams to inform the design and/or analysis of a particular material. Provide the name and citation for the paper. In a few sentences, specify the following:

a

The material system/phase diagram being used (e.g. Cu-Zn, Sn-Pb, etc.)

✓ Answer

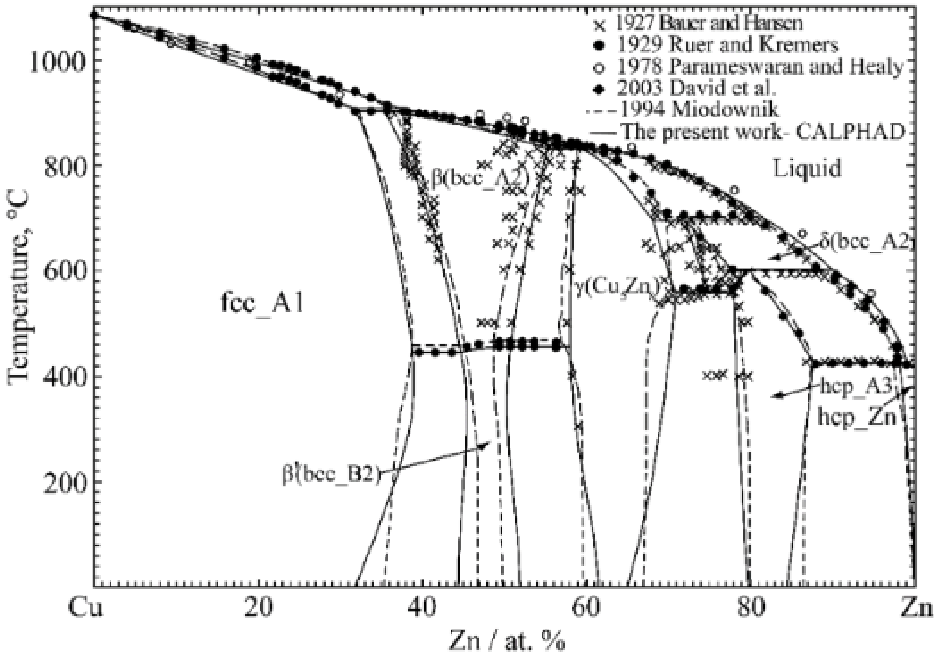


Figure 1. The calculated phase diagram of the Cu-Zn system compared with the experimental data from refs. [36,37,43,58].

Critical Evaluation and Thermodynamic Optimization of the Cu-Zn, Cu-Se and Zn-Se Binary Systems
https://www.mdpi.com/2075-4701/12/9/1401

b

The desired design result (e.g. changing a particular property, troubleshooting a manufacturing process)

✓ **Answer**

To refine and create a more accurate phase diagram for various Cu binary eutectic systems in order to predict how other Cu binary eutectic systems will act.

c

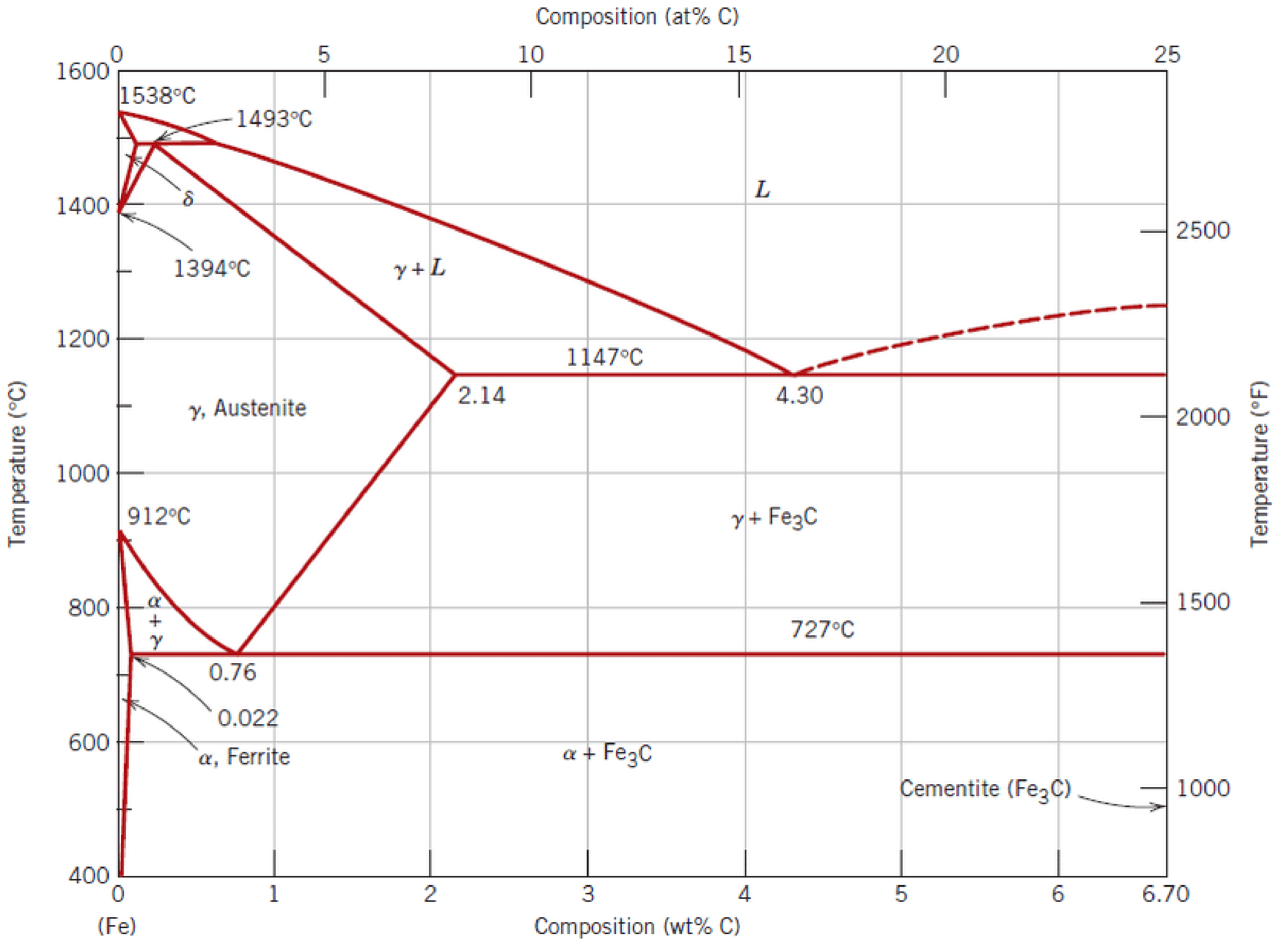
How the authors used phase diagrams to achieve their result

✓ **Answer**

By creating the phase diagrams, the achieved their result.

3

To the right is the iron-iron carbide phase diagram, which we have examined in class. As a reminder, this phase diagram extends from 0 wt% C to 6.70 wt% C, with an intermetallic compound (cementite, Fe3C) existing at 6.70 wt% C. Though we have mostly used the lever rule in simpler phase diagrams, but we can also employ it to determine mass/weight fractions for more complex systems. Consider a 0.25 wt% C – 95.75 wt% Fe alloy.



a

Using the lever rule, what are the mass fractions of the α and γ phases at 750°C? Show all work.

✓ **Answer**

Left Side: 0.05%
Overall composition: 0.25%
Right Side: 0.6%
Tie Length: 0.55%

$$W_\alpha = \frac{0.35}{0.55} = 0.636 = 64\%$$
$$W_\gamma = \frac{0.2}{0.55} = 0.364 = 36\%$$

b

What are the mass fractions at 600°C? Show all work. (Hint: remember that below the eutectic isotherm, the compositions of each phase are determined by the compositions at the eutectic isotherm)

✓ Answer

Left Side: 0.05%
Overall composition: 0.25%
Right Side: 6.70%
Tie Length: 6.65%

$W_\alpha = \frac{6.45}{6.65} = 96.99\%$
$W_{\mathrm{Fe_3C}} = \frac{0.2}{6.65} = 3.01\%$

4

Name the 2 stages involved in the formation of particles of a new phase. Briefly describe each, including the driving forces behind each stage.

✓ Answer

Nucleation: emergence of particles of a different phrase which grows.

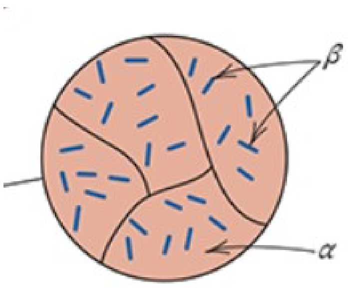
- This happens due to the uneven change in free energy due to temperature and atomic properties

Growth: when the nuclei grow in size from the nucleation sites

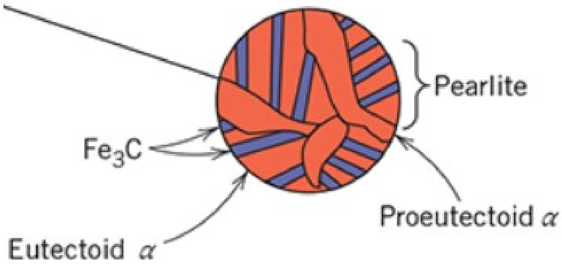
- Happens due to diffusion, effecting the temperature of nearby particles

5

Consider two different microstructures:



15wt% Sn - 85wt% Pb gradually cooled from 350°C to 100°C.



0.25wt% C – 99.75wt% Fe alloy gradually cooled from 900°C to 700°C.

In terms of the *driving forces behind nucleation and diffusion*, why do these microstructures develop differently? (Hint: think about homogeneous vs heterogeneous nucleation)

✓ Answer

The left one shows homogenous nucleation and the right show heterogenous nucleation.
Heterogenous has lower energy costs, it can happen at lower temperatures, while homogenous nucleation does not have this benefit.