Mat Sci 103 – Phase Transformations and Kinetics

Spring Semester, 2020

Homework Assignment 5

Posted: February 21, 2020
Due: Friday, February 28, 2020 by 11:59 pm on the bCourses website.
Instructions:

- Please complete all parts of all problems.
- All homework assignments must be submitted in electronic format to the course website. No late submissions will be accepted.

1. Table 1 below gives the compositions of 8 ternary solutions.

Table 1: Compositions of 8 ternary A-B-C solutions in mole fraction.

Composition	x_A	x_B	x_C
1	0.35	0.65	0.00
2	0.50	0.00	0.50
3	0.25	0.70	0.05
4	0.10	0.40	0.50
5	0.10	0.30	0.60
6	0.80	0.05	0.15
7	0.40	0.20	0.40
8	0.05	0.05	0.90

a. On the Gibbs triangle in Fig. 1 on the next page, plot the 8 compositions listed in Table 1. Illustrate the technique that you used plot the compositions for point 3.

b. In Fig. 1, consider a line that extends from the pure-B corner through composition 2 in Table 1. Give an expression for x_A and x_C in terms of the mole fraction x_B for all compositions on this line.

c. Suppose we desire to prepare a composite material that combines a pure B metal with a ceramic that has composition AC. Identify which of the compositions in Table 1 could correspond to such a composite material, and for this composition give the phase fraction of B and AC.

d. Consider a three-phase ($\alpha+\beta+\gamma$) tie triangle in a ternary phase diagram, where the phases α and β and γ have compositions 6, 7 and 8 from Table 1, respectively. Calculate and write down the composition of a solution having phase fractions of α and β equal to 0.4 and 0.4, respectively. Plot this point and the tie triangle in Fig. 1.

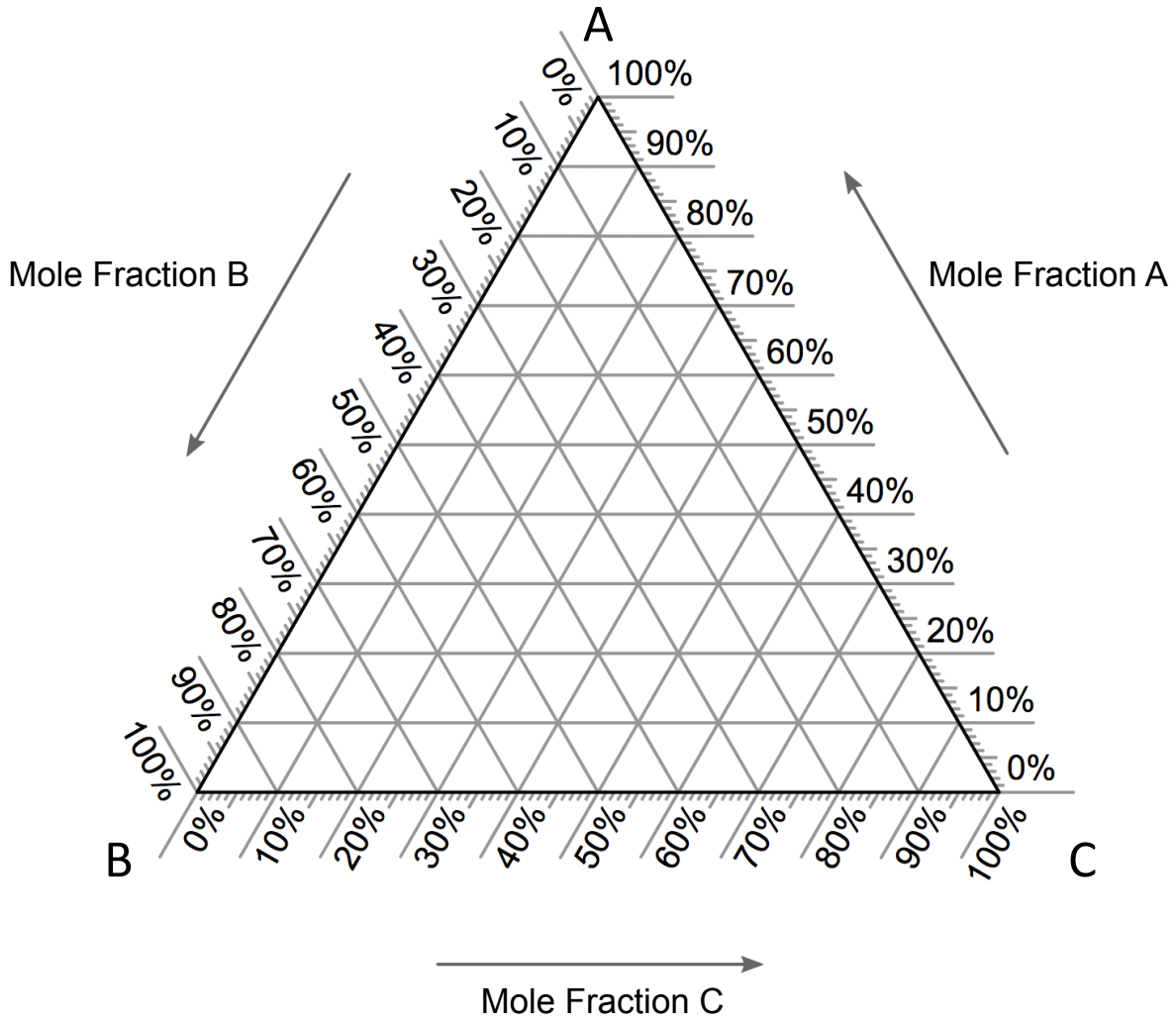


Figure 1: Gibbs triangle for a ternary A-B-C system.

2. Figure 2 shows an isothermal section for the Al-Fe-Ni phase diagram at T=1327°C, taken from the ASM phase diagram compilation online. This phase diagram is relevant to the design of so-called "Fe superalloys" that are strengthened by NiAl precipitates. The phase diagram features 5 phases that will be referred to as follows:

γ (Fe,Ni) fcc solid solution
α (Fe)rt bcc solid solution
γ' Ni_3Al intermetallic compound with $L1_2$ crystal structure
β (FeAl,NiAl) intermetallic compound with B2 crystal structure
L Liquid

The blue line gives one representative tie line. The black point represents an arbitrary alloy composition.

a. Label the two-phase and three-phase regions in Figure 2 using the above Greek symbols to identify the solid phases.

b. For all of the two-phase regions, except that for the small $\beta + \gamma'$ equilibria, sketch plausible tie lines. Draw at least four plausible tie lines in each of these two-phase fields.

c. An alloy sample is heat treated at T=1327°C and the microstructure is measured to have equal mole fractions of austenite (γ phase) and ferrite (α phase). The Fe concentration in both of these phases is measured to be 80 at. %. Given this information, compute the overall alloy composition and plot this composition on Figure 2. Also indicate the tie line corresponding to this phase equilibrium and from the endpoints on this tie line compute the Ni content in the α and γ phases.

d. Indicate by a solid square on Fig. 2 the composition of a solution that will give rise to a three-phase equilibrium between α, γ and L phases with phase fractions of 0.4, 0.3 and 0.3, respectively.

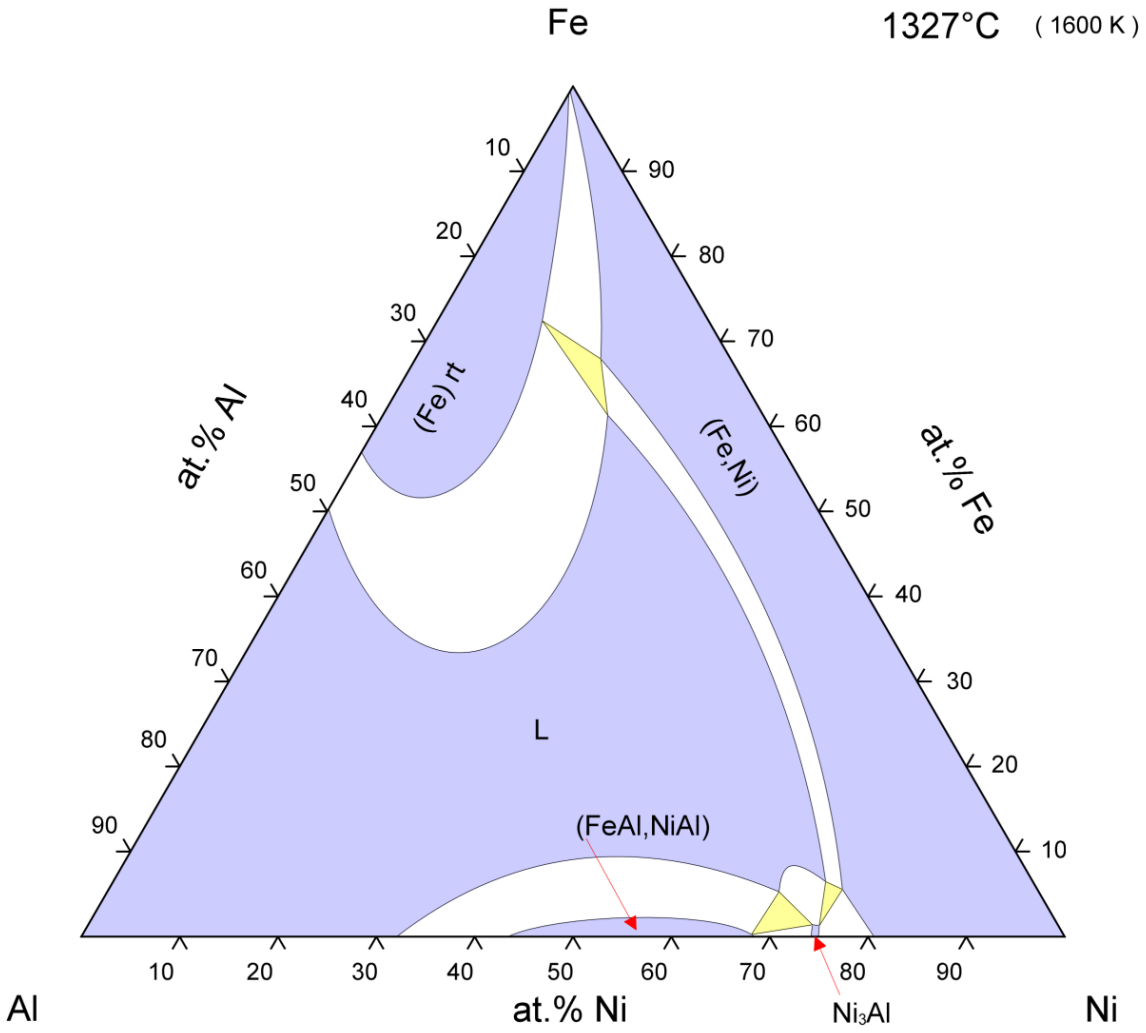


Figure 2: Isothermal section of the Al-Fe-Ni phase diagram at $T = 1327°C$. Taken from the ASM phase diagram compilation.

3. Figure 3 shows a liquidus projection for the Al-Ge-Si system. Al-Ge has a eutectic phase diagram with a eutectic temperature of 420°C and there is negligible solubility of Al in solid Ge and negligible solubility of Ge in solid Al. Similarly, Al-Si has a eutectic phase diagram with a eutectic temperature of 577°C and negligible solubility in the solid phases. Ge-Si has a lens-type phase diagram with complete solubility of Si and Ge in the solid phase.

    a. Using the liquidus projection and the information above, sketch isothermal sections at the following temperatures: 1300°C, 600°C and 500°C in the space provided on the next page. Note that for each of these temperatures on the next page, the relevant line from the liquidus projection is reproduced.

    b. On your plots from part (a) indicate two-phase and three-phase regions and for the two-phase regions draw plausible tie lines.

    c. Consider an alloy containing with x_{Al}=0.9, x_{Ge}=0.05 and x_{Si}=0.05 equilibrated at 500°C. What phases are present and what are their compositions and phase fractions.

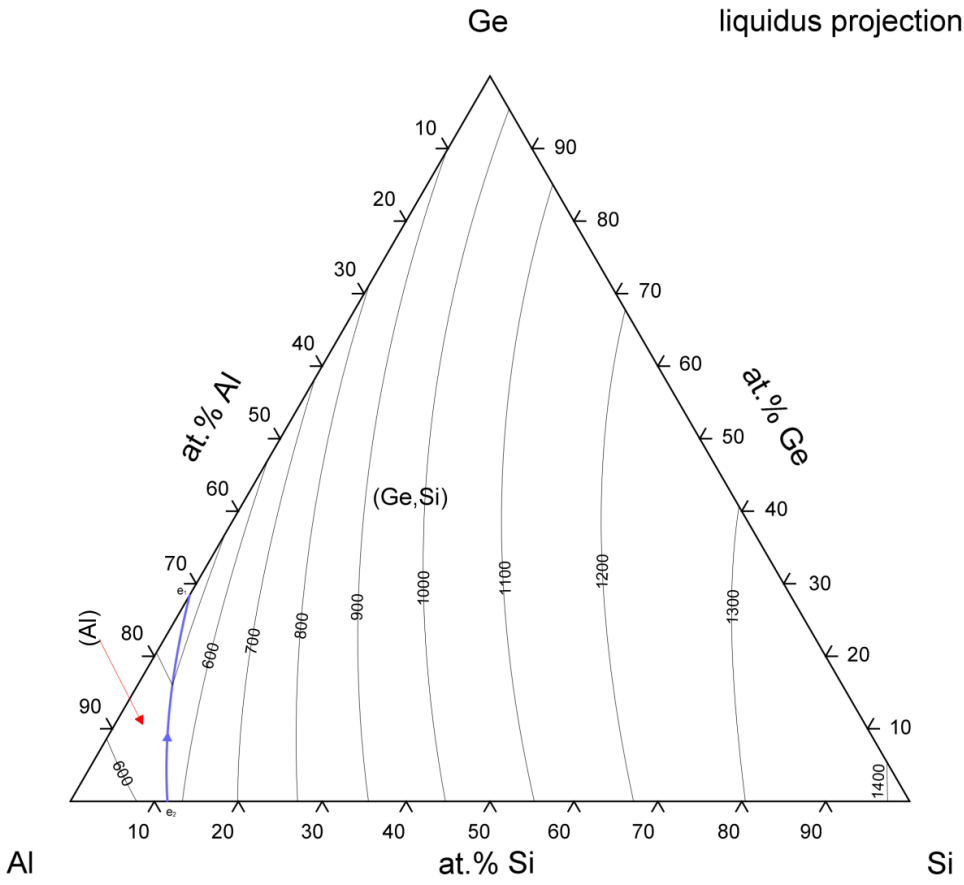
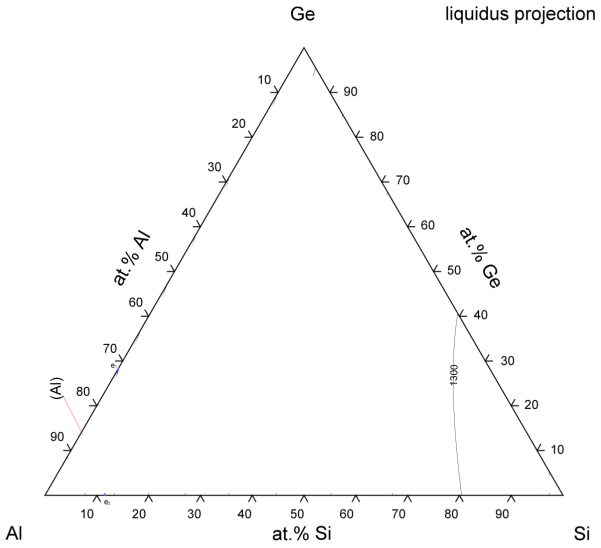
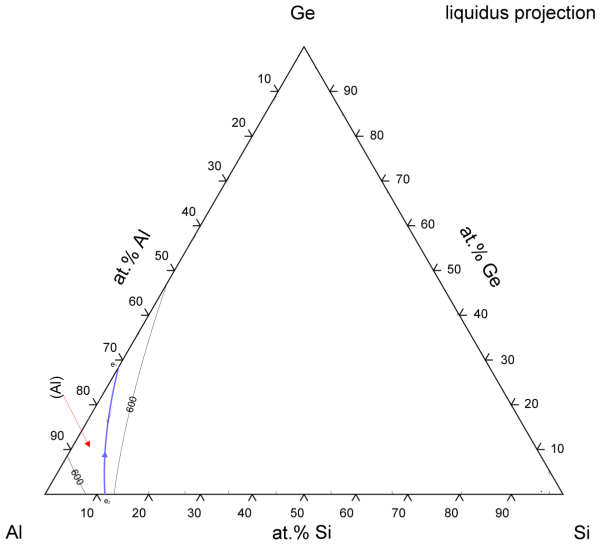
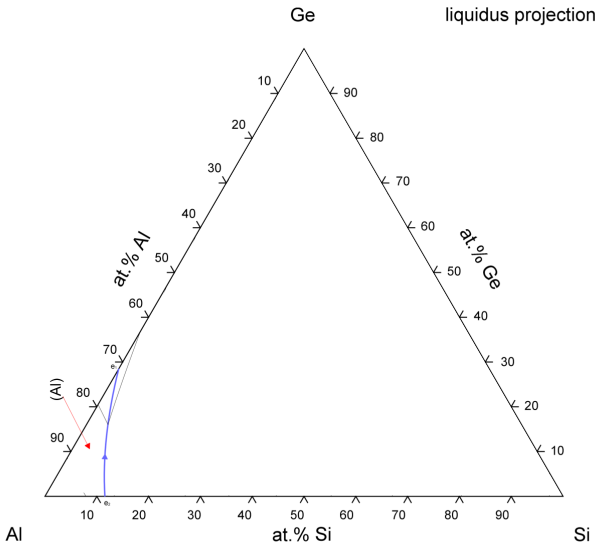


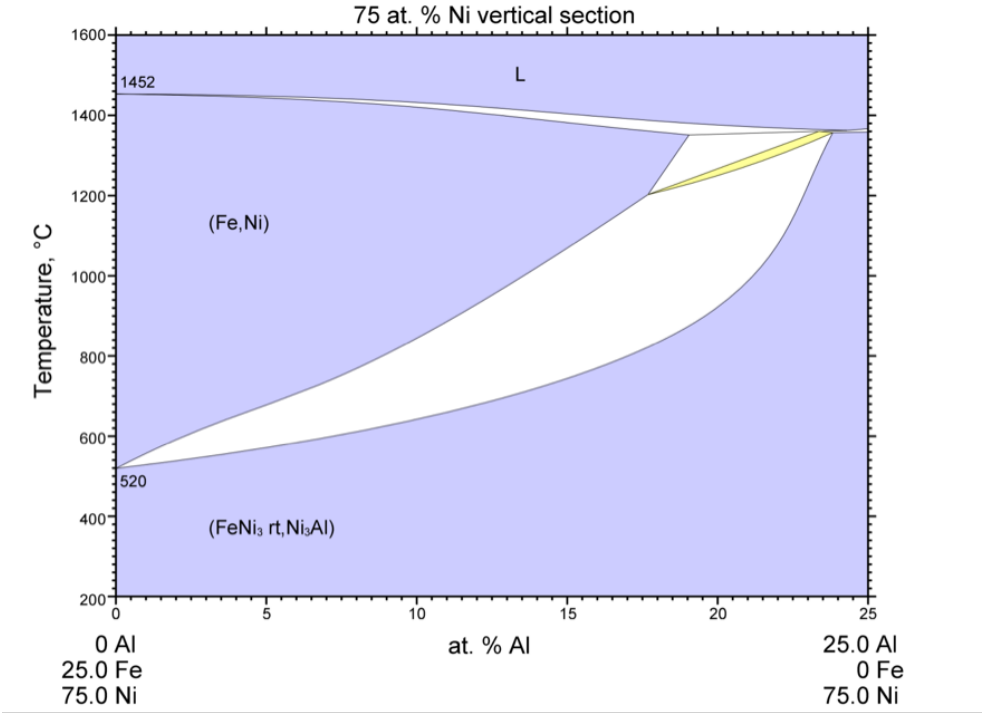
Figure 3: Liquidus projection of the Al-Ge-Si systems, taken from the ASM website.


Ge
liquidus projection
at.% Al
at.% Ge
(Al)
1300
Al
at.% Si
Si


Ge
liquidus projection
at.% Al
at.% Ge
(Al)
600
600
Al
at.% Si
Si


Ge
liquidus projection
at.% Al
at.% Ge
(Al)
Al
at.% Si
Si

4. Shown below is a vertical section and an isothermal section of the Al-Fe-Ni phase diagram. The vertical section is along a line of constant Ni concentration (75 at. %). By considering the vertical section, determine the temperature of the isothermal section.



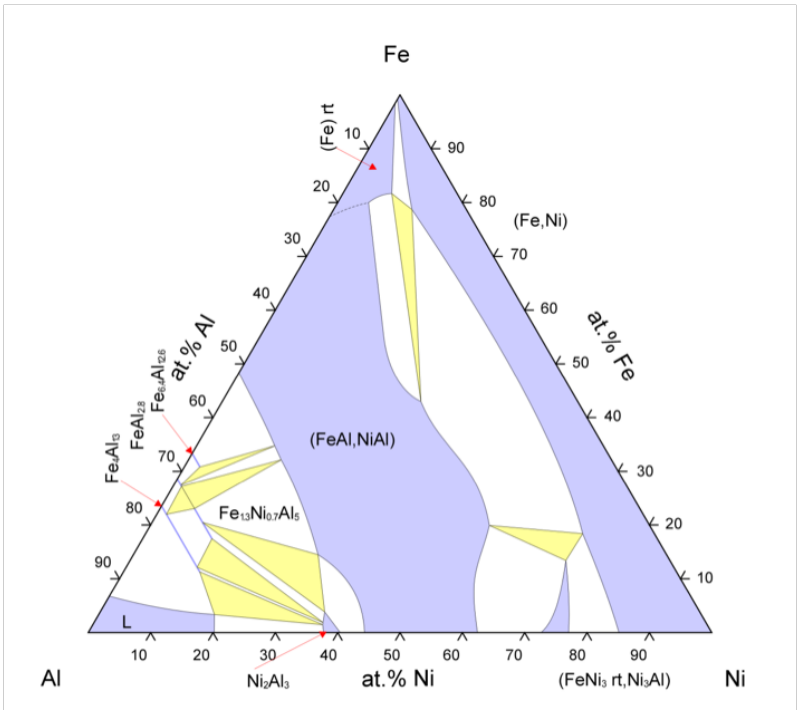


Figure 4: Isothermal section and vertical sections (isopleths) for the Al-Fe-Ni system. Taken from the ASM compilation online.