3.020, Spring 2021
Thermodynamics of Materials
Problem Set 7

Massachusetts Institute of Technology
Department of Materials Science and Engineering

Due April 23, 2021 at 10am EDT

We encourage you to work in groups. If you do so, please note the names of your groupmates on the first page of your solutions.

Remember to clearly present your solutions, including intermediate steps. Failure to show your work may result in reduced credit. Sloppy presentation may result in reduced credit.

Thermo 7.1: Common tangent construction [15 pts]

Prove that the Gibbs free energy of a system composed of two phases connected by a common tangent in a free energy-composition diagram is lower than it would be in a single phase for any solution model above the common tangent line.

Thermo 7.2: Interpreting binary phase diagrams [15 pts]

Below we present several binary phase diagrams. In each case, we ask you to identify reference states and draw plausible free energy-composition diagrams (including relevant common tangents) at a given temperature. As an example, here is the Ni-Ti phase diagram:
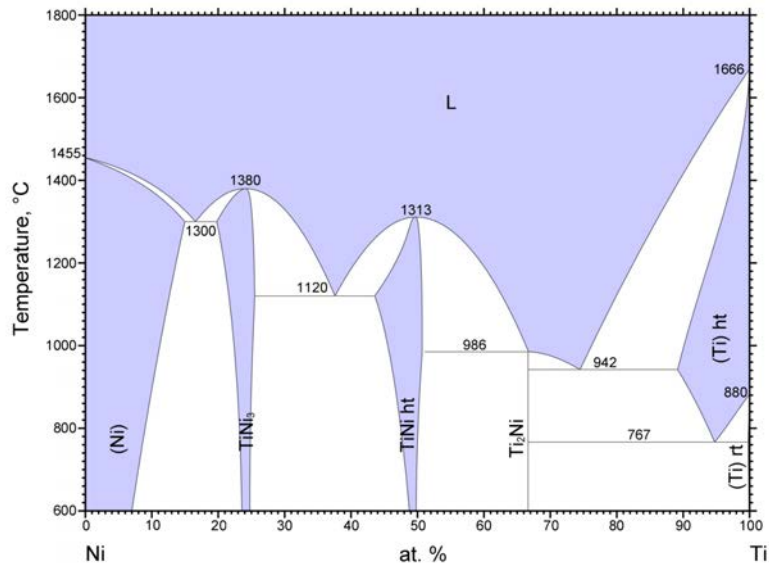
The reference states for Ni at 1200 and 1500 °C are FCC and liquid, respectively. The reference states for Ti at 1200 and 1500 °C are both BCC. Note that I had to look up the crystal structures for the elements, including the high-temperature ("ht") modification of Ti. The room-temp and high-temp crystal structures of Ti are often labeled α and β, respectively. As is often the case in thermodynamics, you need to do some triangulation between the way things are represented in different data sources. Here is a plausible sketch of the free energy-composition diagram at 1500 °C:
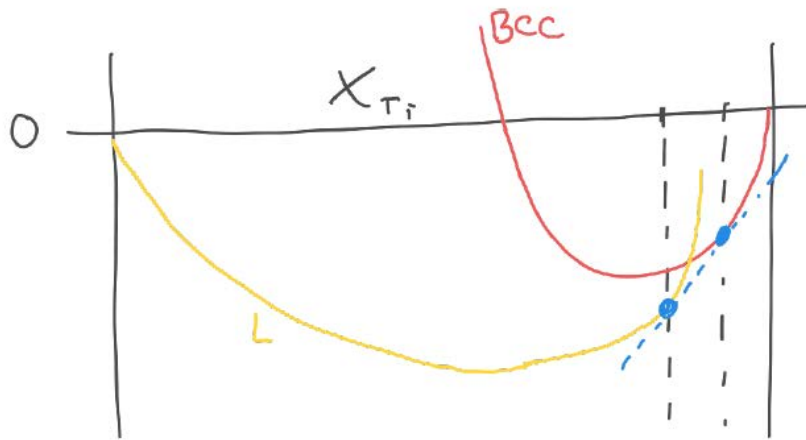
The relevant phases are labeled, the common tangent is drawn, and the composition of the two phases in equilibrium are approximately indicated. We don't draw the solution models across the whole composition range because there's no need - for instance, we don't need to indicate what would be the free energy of pure Ni in the BCC structure at 1500 °C to complete this diagram.

(a) [5 pts] Here is the Si-Ge system:
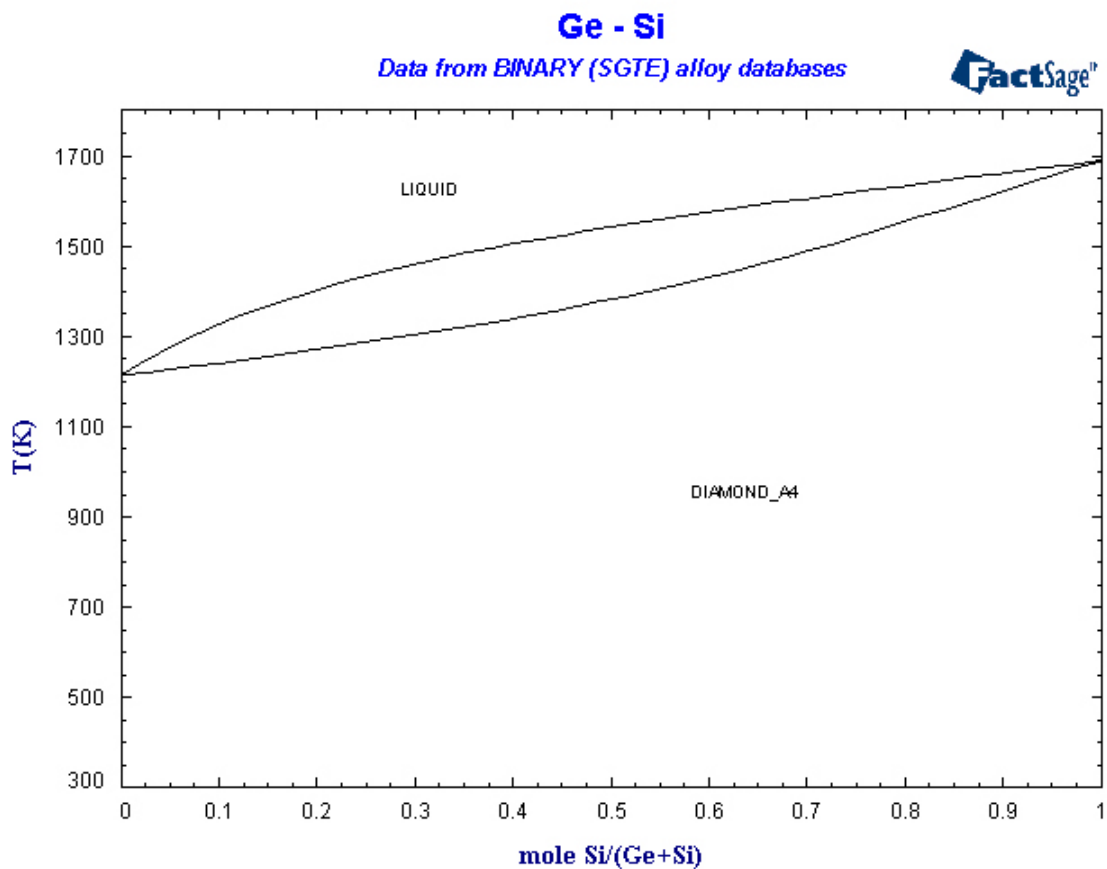
Please identify the reference states and draw a plausible free energy-composition diagram for this system at 1400 K.

3

(b) [5 pts] Here is the Au-Si system:
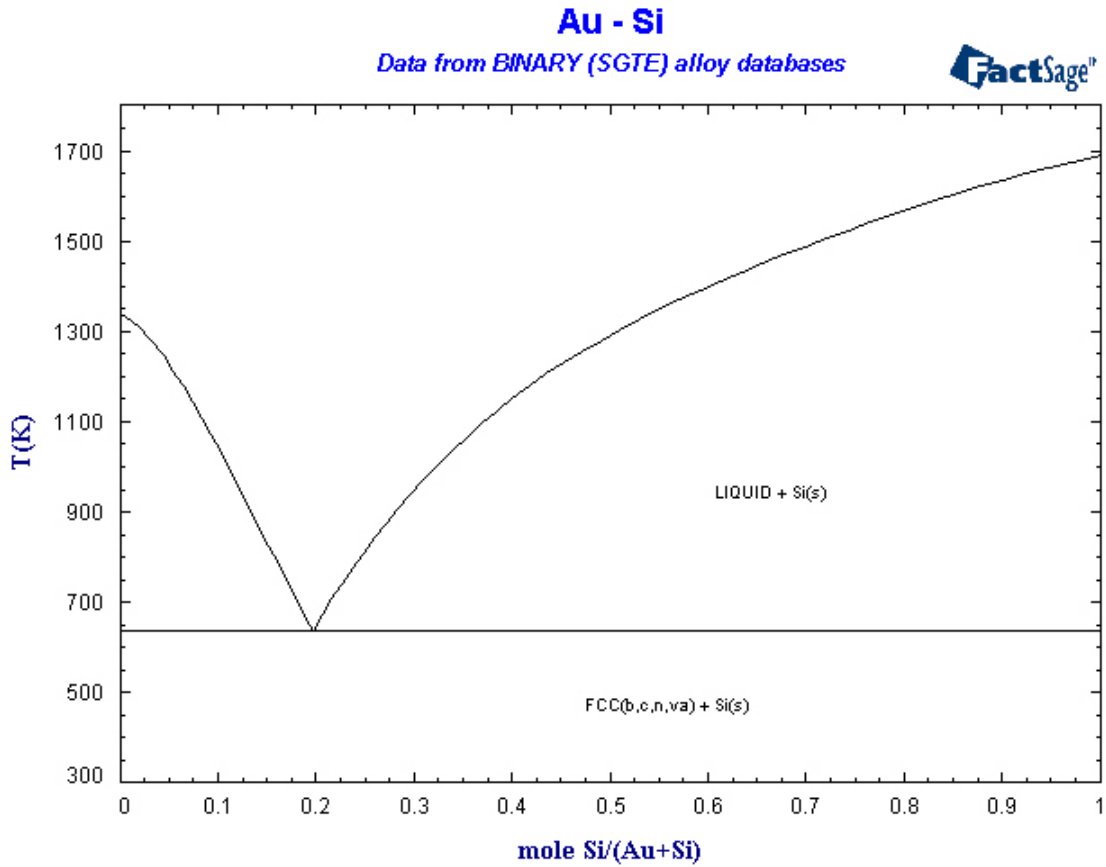
Au - Si
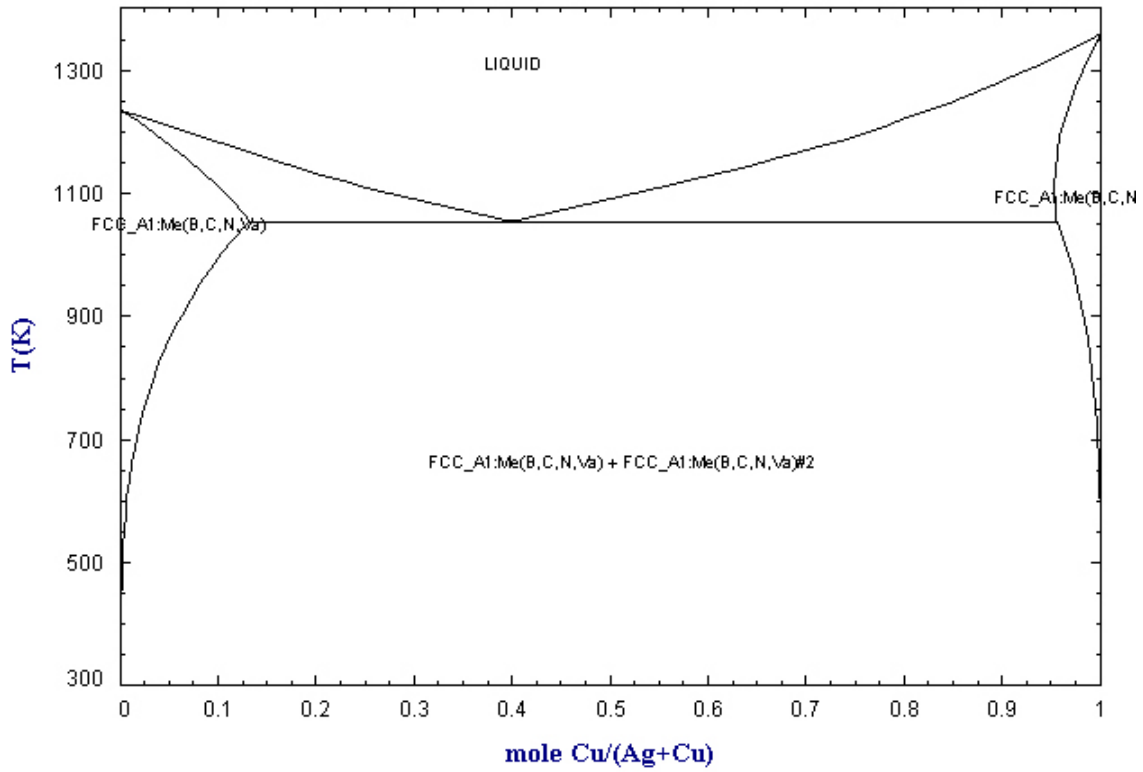
Data from BINARY (SGTE) alloy databases

FactSage

Please identify the reference states and draw a plausible free energy-composition diagram for this system at 1400 K.

(c) [5 pts] Here is the Ag-Cu system:

Ag - Cu

Data from BINARY (SGTE) alloy databases

LIQUID

FCC_A1:Me(B,C,N,Va)

FCC_A1:Me(B,C,N

FCC_A1:Me(B,C,N,Va) + FCC_A1:Me(B,C,N,Va)#2

T (K)

mole Cu/(Ag+Cu)

Please identify the reference states and draw a plausible free energy-composition diagram for this system at 1000 K. *Note: The solid solution phases on either side of the diagram are both FCC, the labels are a bit hard to read.*

3.020 Thermodynamics of Materials
Spring 2021