Homework 5 Properties of Materials

1) Describe the stages of steel production beginning with iron ore and coal.

2) Mixing of two liquids or gases can be modeled using a lattice model, Boltzmann's expression for entropy and a term expressing the average enthalpy of mixing.

a) Give an expression for the free energy change on mixing and indicate the entropic and enthalpic components of this expression.
b) Sketch this free energy change as a function of composition for several values of the enthalpic interaction parameter above, below and at the critical temperature.
c) How can the expression for the free energy be used to calculate the phase diagram?
d) Sketch the phase diagram (T versus composition) for a binary system displaying an upper critical solution temperature.
e) Show how the composition and amounts of the two phases in the phase separated UCST system can be determined using the lever rule.

3) a) For a binary isomorphous system sketch the phase diagram showing the liquidus and solidus lines and the composition of the phases. (Define this type of system.)
b) For a binary eutectic system sketch the phase diagram showing the liquidus, solidus, solvus lines and the eutectic isotherm and eutectic point.
c) Explain what an intemediate solid solution is in the Cu-Zn phase diagram.
d) Explain what an intermetallic compound is in the Mg-Pb system.
e) Define Eutectoid, Eutectic and Peritectic and show examples of these reactions in the Cu-Zn system and in the Fe-C system for steel.

ANSWERS: Homework 5 Properties of Materials

1) See web page on steel production: http://www.ais-metallurgical-testing.com/metallurgical-tutorial/

2) a) $\frac{\Delta G}{NkT} = \phi_A \ln \phi_A + (1-\phi_A)\ln(1-\phi_A) + \phi_A(1-\phi_A)\chi$

The first two terms are entropic. The last term is enthalpic.

b)

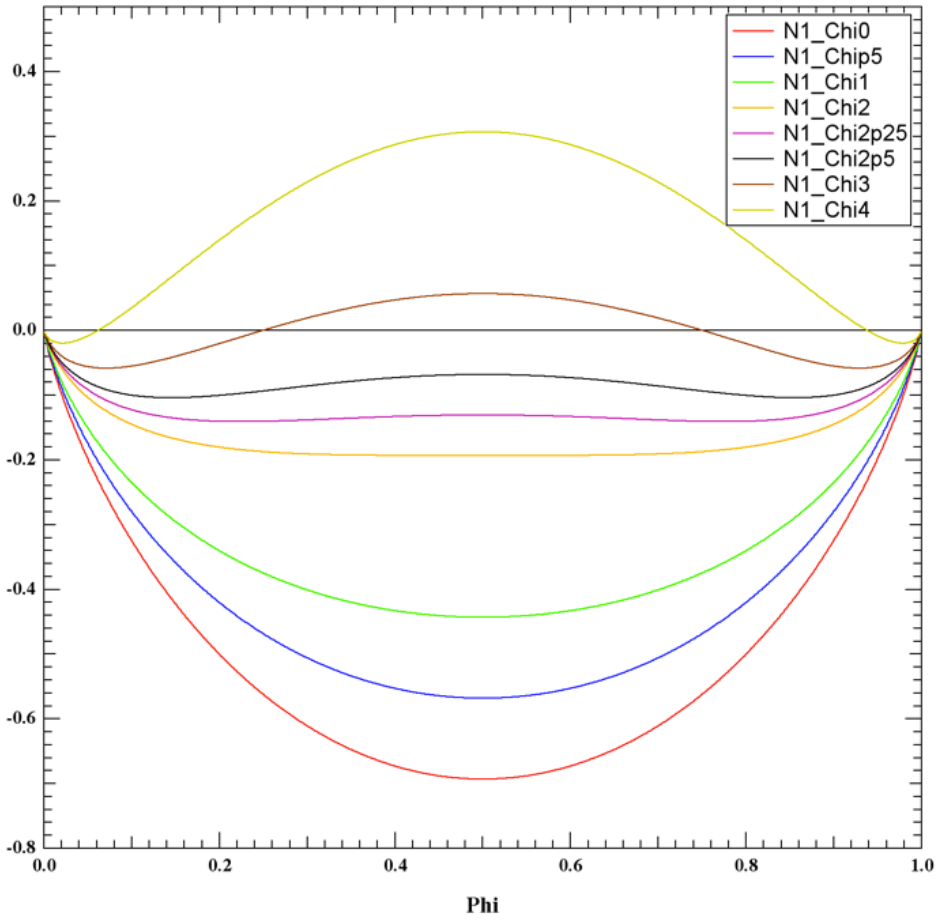


Figure 1. $\Delta G/NkT$ versus ϕ for equation (4) with χ = 0; 0.5; 1; 2; 2.5; 3 and 4.

The critical point occurs when the interaction parameter equals 2.

c) The minima in the curves of Figure 1 are points of equal chemical potential (derivative of free energy with composition) meaning that the compositions are at equilibrium. These points yield the cloud point curve since each value of the interaction parameter corresponds to a temperature, $\chi = z\langle \Delta\varepsilon \rangle / kT$. The cloud point curve can also be constructed from the first derivative of the free energy with respect to composition.

d)

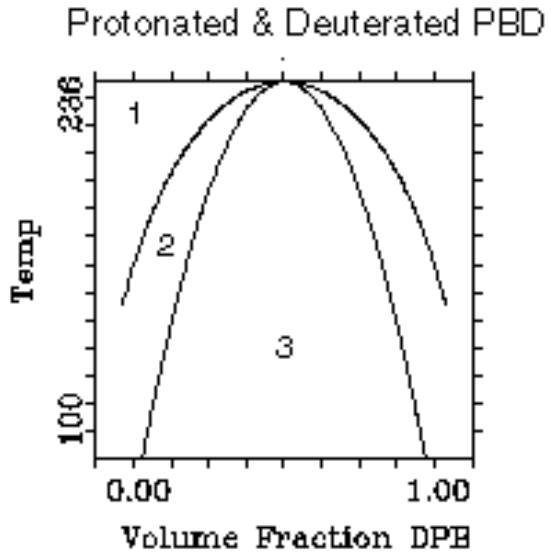
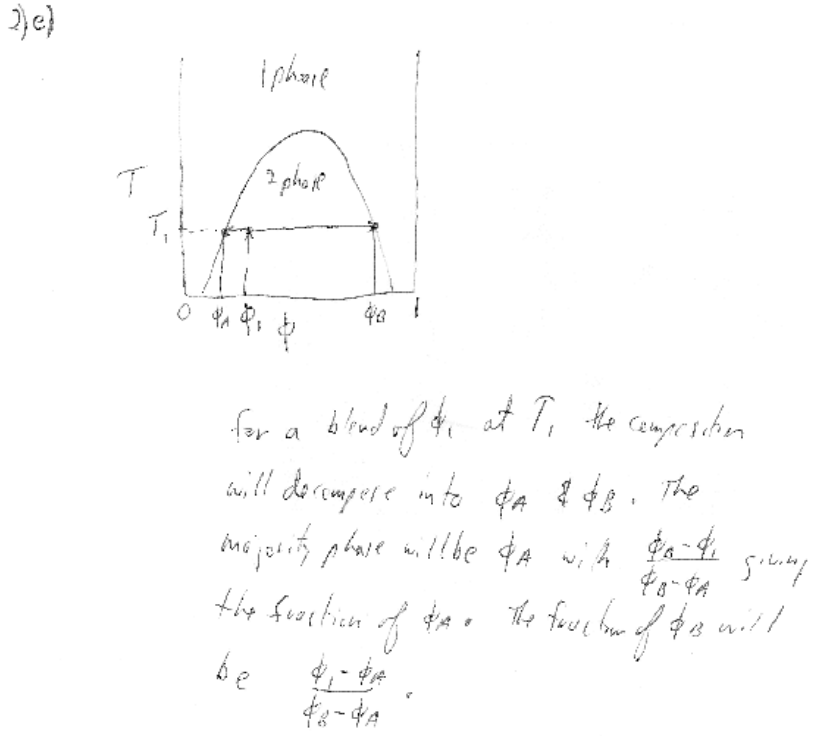
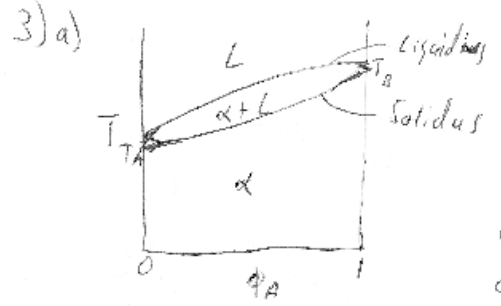


Figure 2. Upper critical solution temperature phase diagram. Regions 2 and 3 are 2-phase regimes, region 1 is the single phase regime. The line between region 2 and 1 is the cloud point curve or the binodal curve.

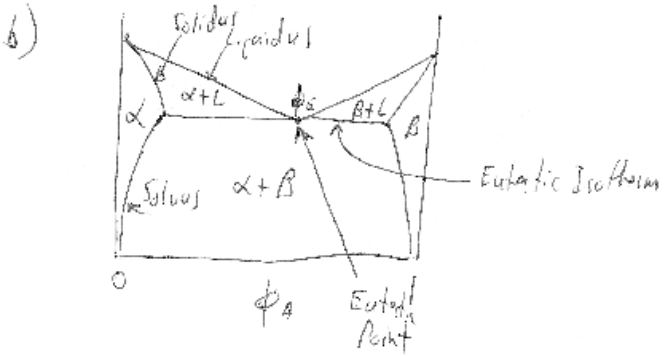
e)



3) a)

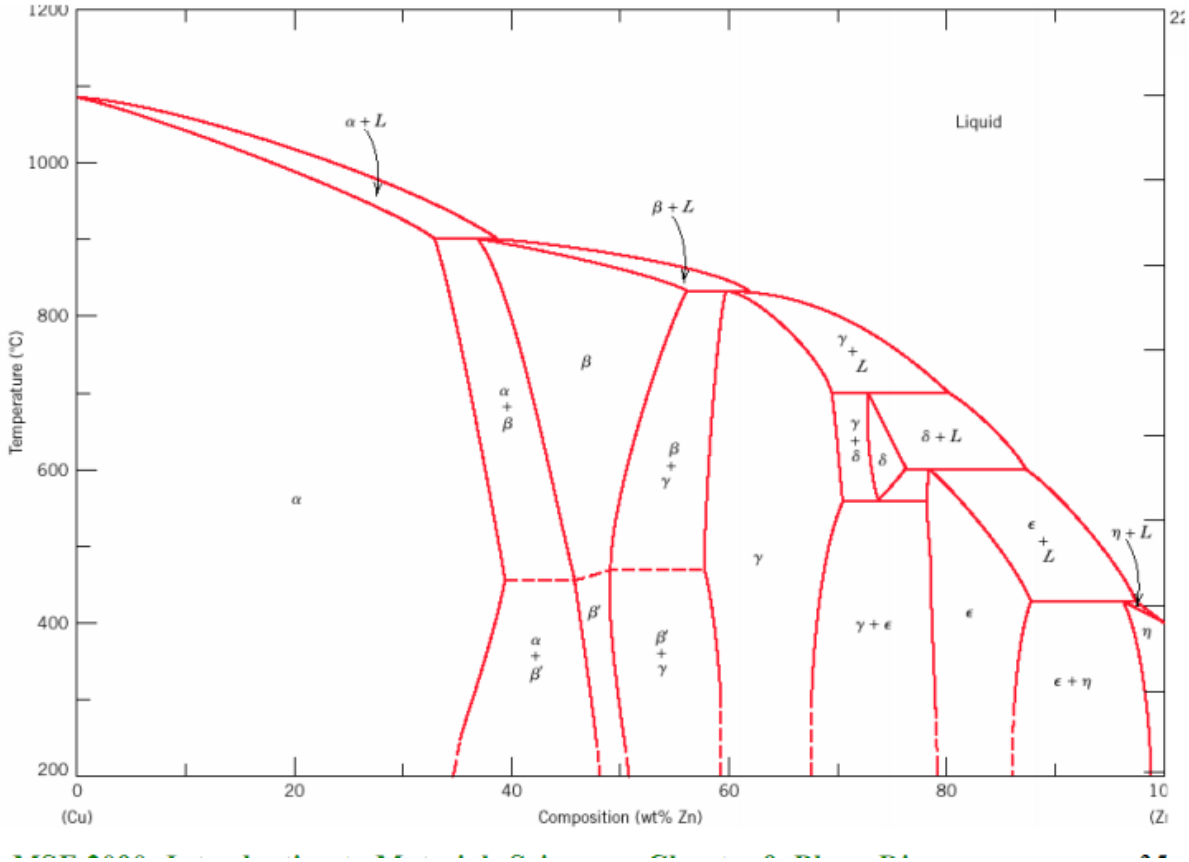


A & B have the same crystal structure and close to the same atomic size. A & B make a solid solution.

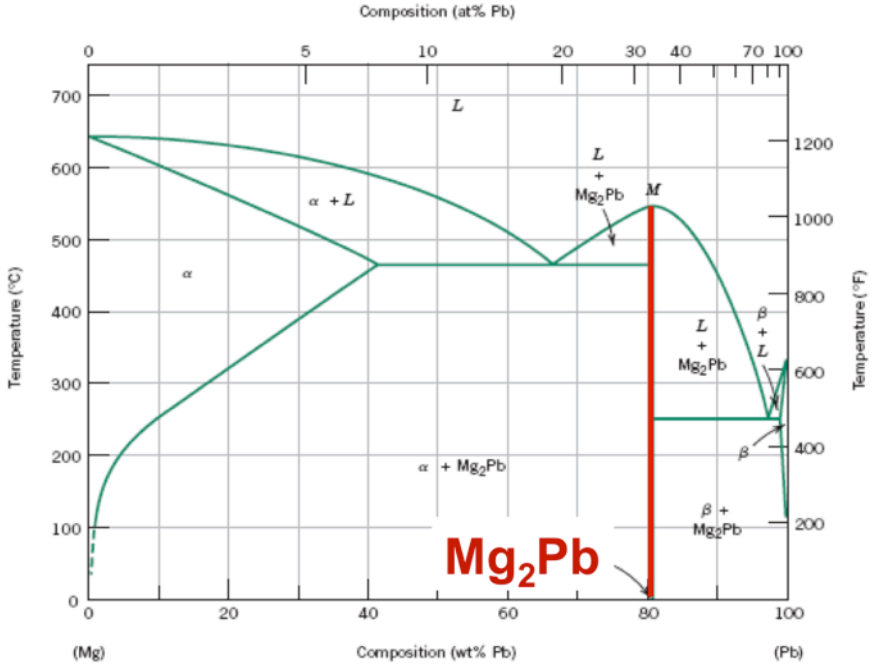


c)

Example: in Cu-Zn, α and η are terminal solid solutions, β, β', γ, δ, ε are intermediate solid solutions.

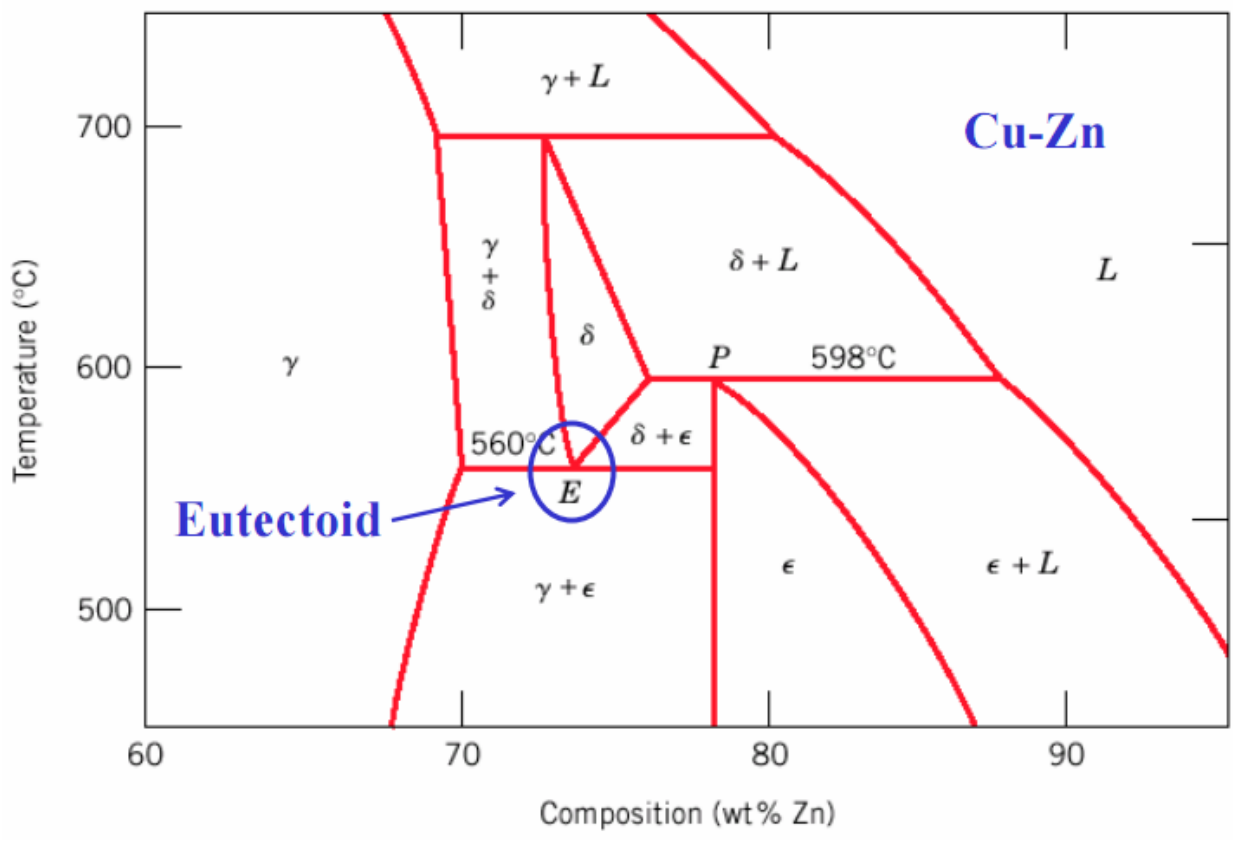


d)



Note: intermetallic compound exists as a line - not an area – because stoichiometry (i.e. composition of a compound) is fixed.

e)


Cu-Zn
γ + L
δ + L
L
γ + δ
γ
δ
P
598°C
560°C
δ + ϵ
E
Eutectoid
γ + ϵ
ϵ
ϵ + L
700
600
500
60
70
80
90
Temperature (°C)
Composition (wt% Zn)

Eutectic and Eutectoid Reactions