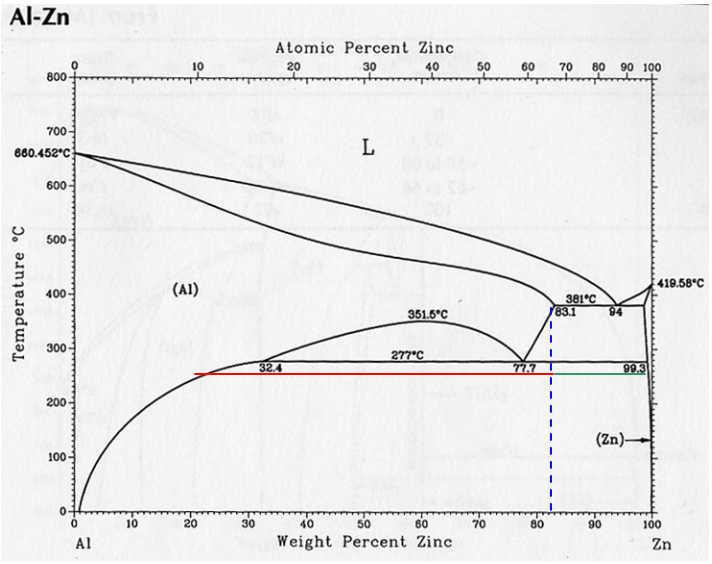
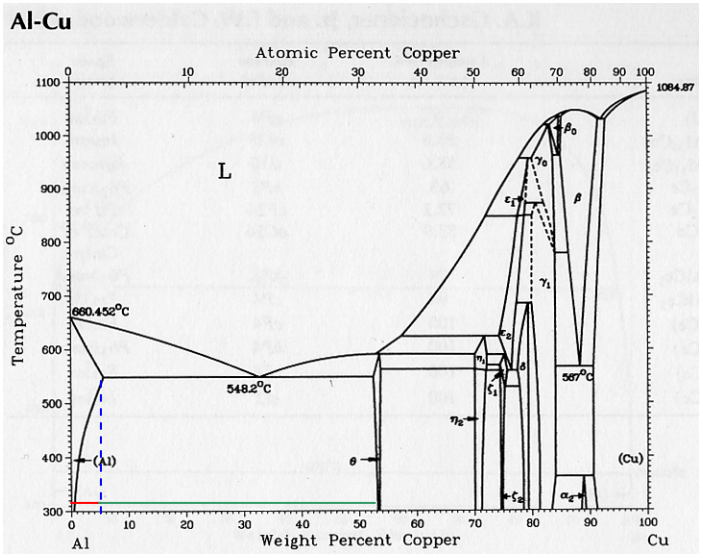
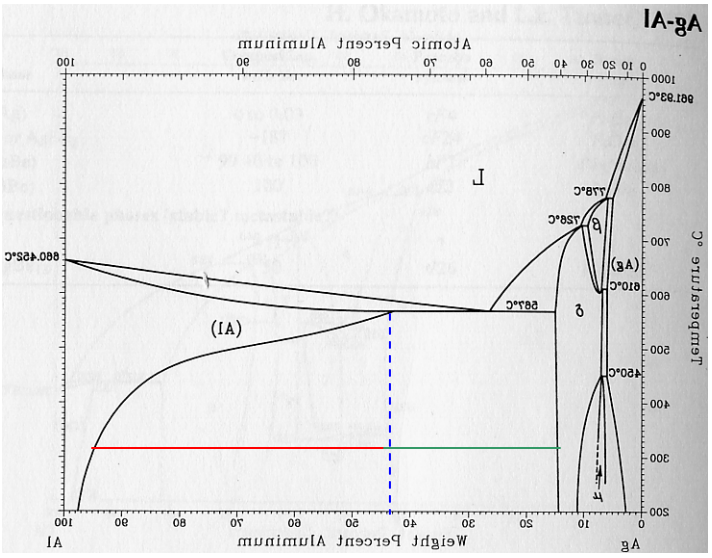
Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.14 Physical Metallurgy – Fall 2003

Solutions to Problem Set #6

6.1 As we briefly discussed in class, three common precipitation-strengthened aluminum systems are Al-Zn, Al-Cu, and Al-Ag. What parameters control the degree of strengthening in these systems? If you had to choose one of the three systems to get the highest strength possible, which would you choose, and why?







Here are their phase diagrams (Ag-Al is backward so that they all have Al on the left). The first thing to consider is the possibility of APB strengthening. Al-Ag and Al-Cu may be strengthened this way, Al-Zn cannot (Al-Zn ruled out relative to Al-Ag). Next, consider the volume fraction of precipitate particles that can be formed. Dissolve as much solute as you can at the eutectic temperature, the cool and allow ppts to form. Then, use the lever rule at a lower temperature and solubility limit. This will also depend on the composition of the precipitate phase. Therefore, between Al-Ag and Al-Cu, the Al-Ag system would give you the highest volume fraction, and since strengthening is proportional to concentration, you'd want to pick **Al-Ag** for maximum strengthening.

6.2 *Following on from 6.1: What parameters control the stability of these systems against coarsening? On this basis, which system would you choose and why?*

Element	T_m (ºC)
Ag	962
Al	660
Cu	1085
Zn	420

If we are concerned with coarsening of precipitates, we want to choose the system with the highest melting temperature. Coarsening of the precipitates will be controlled by the diffusion of Ag, Cu or Zn – and you want the absolute temperature T/T_m to be minimized. On this basis, we should choose the **Al-Cu** system (although Al-Ag is a close second!).

6.3 *The precipitation sequence in many alloys proceeds first through GP zones, then to a metastable phase such as θ''. Considering the structural differences between GP zones and θ'', identify two reasons why θ'' are more beneficial for strengthening as compared with GP*

The θ'' is more beneficial for strengthening as compared to GP zones because θ'' precipitates are larger, coherent, and chemically ordered – so you get strengthening due to **size mismatch** and the formation of **anti-phase boundaries** due to the presence of θ''**.**