1. An Al-5% Cu ingot unidirectionally solidified under the conditions of no diffusion in the solid, complete diffusion in the liquid, and local equilibrium at the interface, so that the Scheil equation applies.

   (a) Calculate the composition of the liquid when the ingot is 50 percent solid.   What is the average composition of the solid?

   (b) What is the interface temperature at this point?

   (c) How much eutectic and second phase θ will   have formed when the ingot is completely solidified?

   (d) Plot the composition profile in the solidified ingot.   (15%)
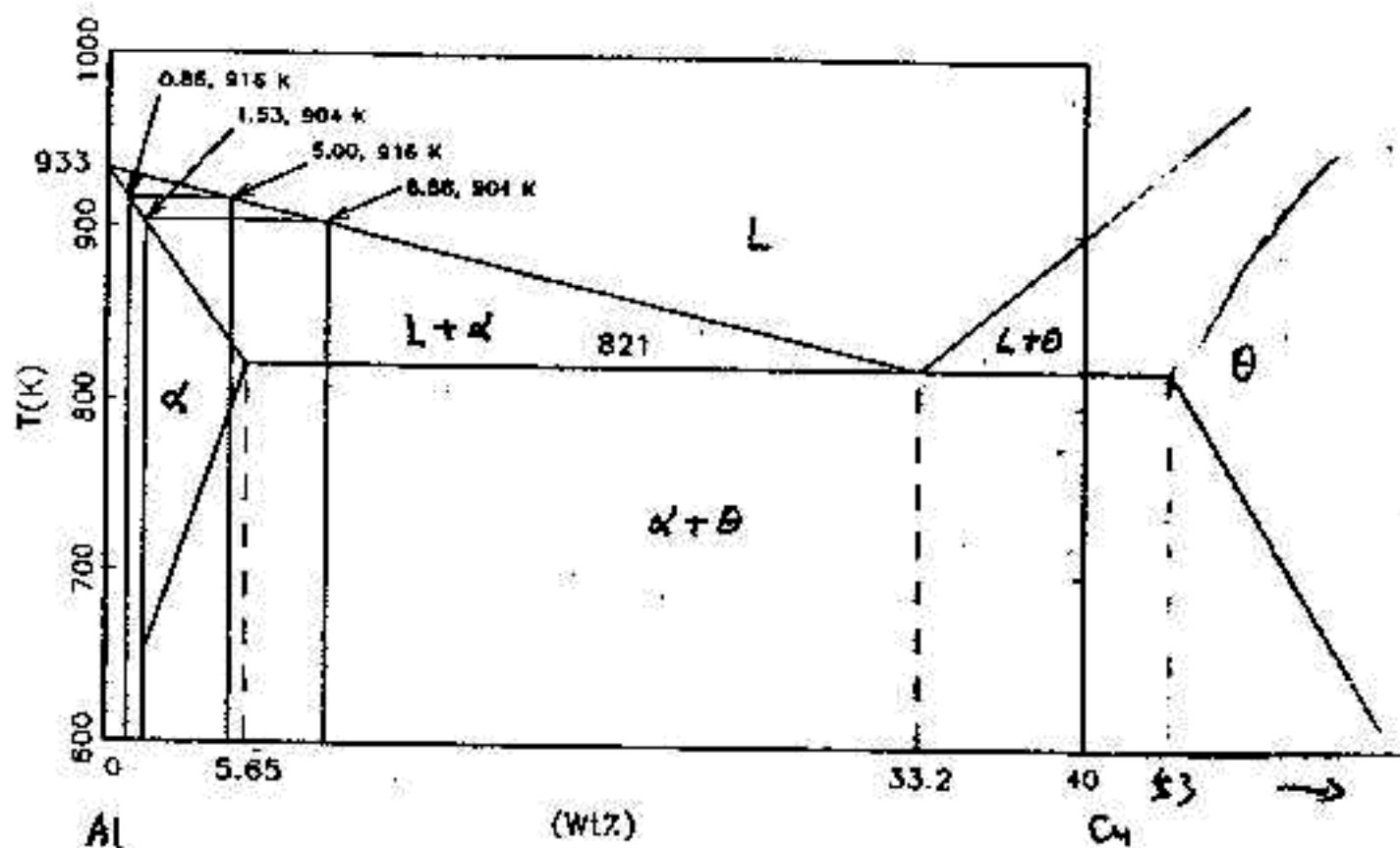
2. If the effective area of the raster of an electron microscope specimen supplying information to the CRT of an electron microscope has a 5 nm diameter and the semicone angle, α, of the electron beam is 0.01 rad.,

    (a) What would be the maximum usable magnification of the microscope if a digital spot on the screen of the CRT has a 100 μm diameter?

    (b) What would be the depth of field at this magnification?

    (c) What would be the depth of field if the microscope were to operate at a magnification of 2000 X?   *(15%)*

3. It is well known that pure copper has superior ductility, however, the Cu-0.05 Bi alloy shows a very poor ductility in tensile tests. Explain the reason for that. *(10%)*

4. (a) Describe briefly how to set up an experiment to measure the hardenability of a steel specimen.

    (b) What variables determine the hardenability of a steel? *(10%)*

5. The number of vacancies in some hypothetical metal increase by a factor of five, when the temperature is increased from 1000 K to 1130 K. Calculate the activation energy for vacancy formation, assuming that the density of the metal remains the same over this temperature range.   *(10%)*

6. It is determined by experiment that the kirkendall markers placed at the interface of a diffusion couple, formed by welding a thin plate of metal A to a similar plate of metal B, move with a velocity of 4.5×10^{-12} m/s toward the A component when the concentration $N_A = 0.38$ and the concentration gradient, dnA/dx, is $2.5 \times 10^{+2}$ per m. The chemical diffusion coefficient $\vec{D}$ under these conditions is 3.25×10^{-14} m²/s. Determine the values of the intrinsic diffusivities of the two components. (15%)

7. For the transformations that occur on cooling, the maximum growth rate usually exists at an intermediate temperature. Explain it. Why this maximum growth rate does not occur in the reverse transformation (transformation on heating)? (10%)

8. One of the major heat treatments of steel is tempering. What is the purpose of tempering? There are a few stages during tempering, please describe them in detail. People sometimes confuse tempering with annealing, please clarify these two terms. (15%)