ENGR 240 - Exam 2 **Name:** STOLK
Spring 2001

Point values are in brackets. 100 points total.

1. **Refer to the attached stress-strain diagrams for samples of four different materials: A, B, C, and D (Figure 1). The end of each curve indicates the fracture point.**

   a. **Which material has the lowest elastic modulus, and what is its value?** [3]

   SAMPLE B ; $E = \frac{\sigma}{\epsilon} \simeq \frac{150\ \text{MPa}}{0.06} = 2.5 \times 10^9\ \text{Pa} = 2.5\ \text{GPa}$

   b. **Which material has the greatest toughness, and how can you tell?** [3]

   SAMPLE C - GREATEST AREA UNDER THE σ-ϵ CURVE

   c. **Which material would exhibit the highest Brinell hardness number?** [2]

   SAMPLE A

   d. **Which material can be plastically deformed the most (most ductile)?** [2]

   SAMPLE C

   e. **After the conclusion of the tests, if the broken halves of each sample were fitted back together, which sample would be the shortest? Assume that all four samples had the same initial length.** [2]

   SAMPLE D - ALL ELASTIC DEFORMATION, SO $l_f = l_0$

Problem 1 (continued) –

f. **A circular rod is to be produced, 15 cm long with a diameter of 5.0 mm. This rod must be able to support an applied tensile stress of 230 MPa without plastically deforming.**

i. **List all the materials (A, B, C and/or D) that would be appropriate.** [3]

A, C, AND D

ii. **If a rod(s) was produced from the material (or materials) listed in part i, which would experience the least amount of total elongation while under the 230 MPa stress?** [3]

A (HIGHEST ELASTIC MODULUS)

iii. **For the material chosen in part ii, determine the amount of total elongation in the rod while under the 230 MPa stress.** [3]

$$\epsilon = \frac{\Delta l}{l_0} \Rightarrow \Delta l = \epsilon l_0 = (0.02)(15\ \text{cm}) = \underline{0.30\ \text{cm}}$$

iv. **For the material chosen in part ii, what applied tensile force would cause the rod to break?** [3]

$$\sigma_{TS} \cong 320\ \text{MPa} = \frac{F}{A_0} \Rightarrow F = A_0\,(320\ \text{MPa})$$

$$= \frac{\pi}{4} d_0^{\,2}\,(320\ \text{MPa})$$

$$= \frac{\pi}{4}(0.005\ \text{m})^2\,(320\ \text{MPa})$$

$$\underline{\underline{F \cong 6.3\ \text{kN}}}$$

2. Refer to the attached cadmium-antimony (Cd-Sb) phase diagram (Figure 2) to answer the following questions.

a. What is the melting temperature of antimony? [2]

630.74°C

b. What is the solubility of antimony in cadmium at 275 "C? [2]

0 wt% Sb IN Cd AT 275°C

c. A Cd-Sb alloy containing 90 wt% Sb is cooled slowly from a temperature of 650 °C.

i. What is the composition of the first solid to form? [3]

$C_\gamma \cong$ 100 wt% Sb

ii. At approximately what temperature will the alloy contain equal amounts of liquid and solid? [3]

550°C

d. A different Cd-Sb alloy, containing 20 wt% Sb, is slowly cooled from 450 °C to room temperature, at which point it consists of two solid phases, α and β (you may assume that the microstructure and phase compositions at room temperature are identical to those that exist just below the material's eutectic temperature).

i. What is the eutectic temperature for this alloy? [2]

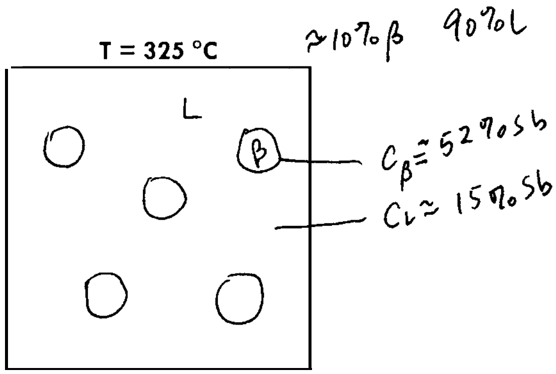
290°C

Problem 2 (continued) –

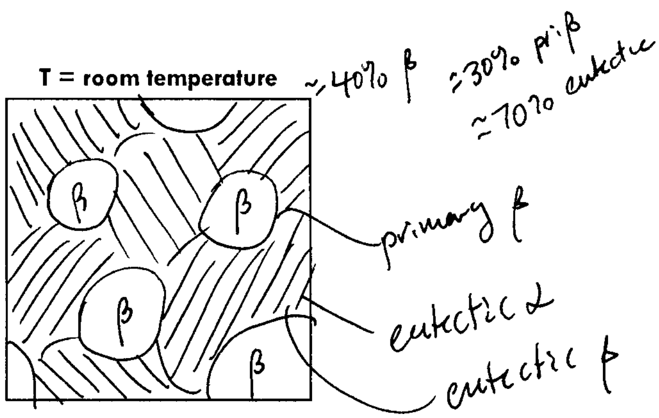
ii. In the boxes below, sketch the microstructures for this alloy (20 wt% Sb) at the specified temperatures. [10]

- Label all phases in your sketches (include designations of "primary" and "eutectic" where appropriate).
- Indicate compositions for all phases in your sketches.

T = 325 °C



T = room temperature



iii. At room temperature, what are the relative amounts (each) of total α and total β in the alloy? [6]

$$W_{TOTAL\ \alpha} = \frac{C_\beta - C_0}{C_\beta - C_\alpha} = \frac{52-20}{52-0} = 0.615 = \underline{61.5\%}$$

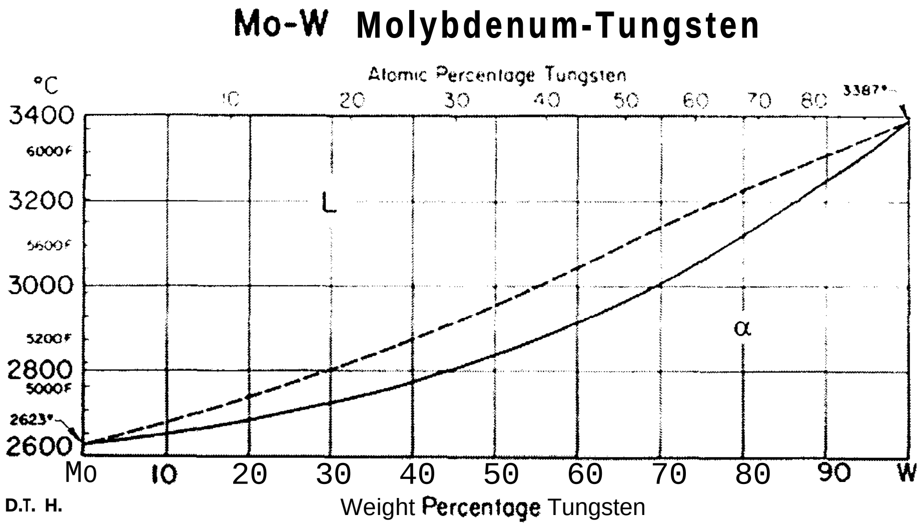
$$W_{TOTAL\ \beta} = \frac{C_0 - C_\alpha}{C_\beta - C_\alpha} = \frac{20-0}{52-0} = 0.385 = \underline{38.5\%}$$

iv. What proportion of the sample at room temperature consists of eutectic α? [3]

$$W_{EUTECTIC\ \alpha} = W_{TOTAL\ \alpha} = \underline{61.5\%}$$

(NO PRIMARY α)

3. Molybdenum and tungsten form a binary isomorphous system, as shown below.



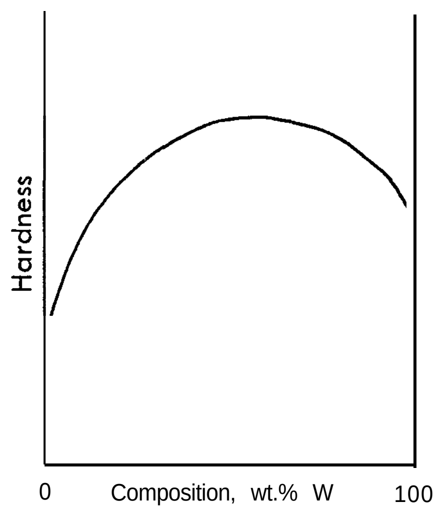
a. Name two similarities that must exist between Mo and W for them to exhibit this type of phase diagram. [3]

- SAME STRUCTURE
- SIMILAR ATOMIC RADII
- SIMILAR ELECTRONEGATIVITY
- SIMILAR VALENCE

b. On the axes below, sketch the expected effect of composition on the hardness of molybdenum-tungsten alloys. [3]

Mo & W → SINGLE PHASE

(SOLID SOLUTION HARDENING)



4. What type of indentation hardness test would be ***best*** suited to measure the hardness of the paint layer on the hood of a 1984 Chevy Camaro? [2]

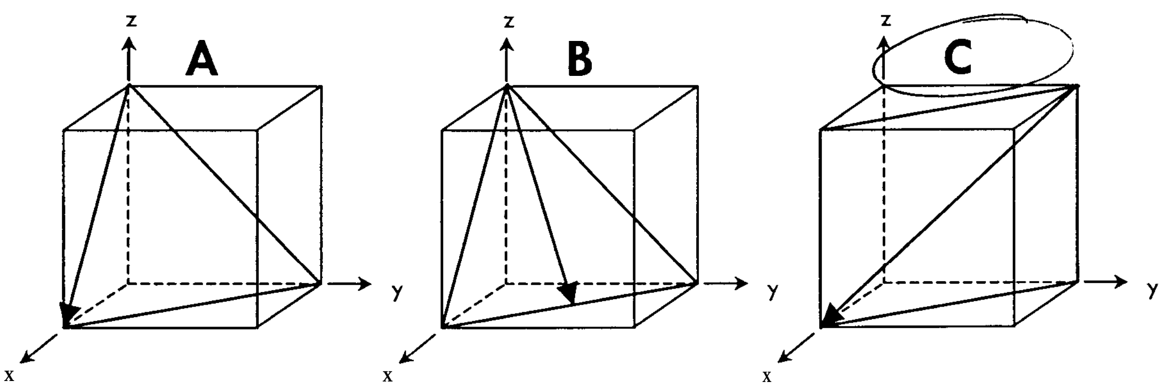
a. Brinell

b. Rockwell

c. Vickers

d. Knoop microhardness

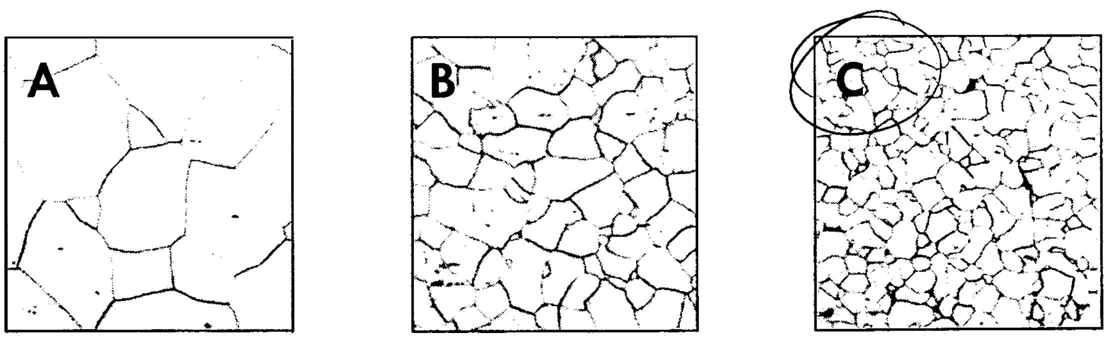
5. Which of the following pictures indicates a preferred slip system for tungsten (bcc structure)? [3]



6. The microstructures of three steel specimens of the exact same composition are shown below. All micrographs were taken at the same magnification.

a. Which specimen would have the highest strength? [2]

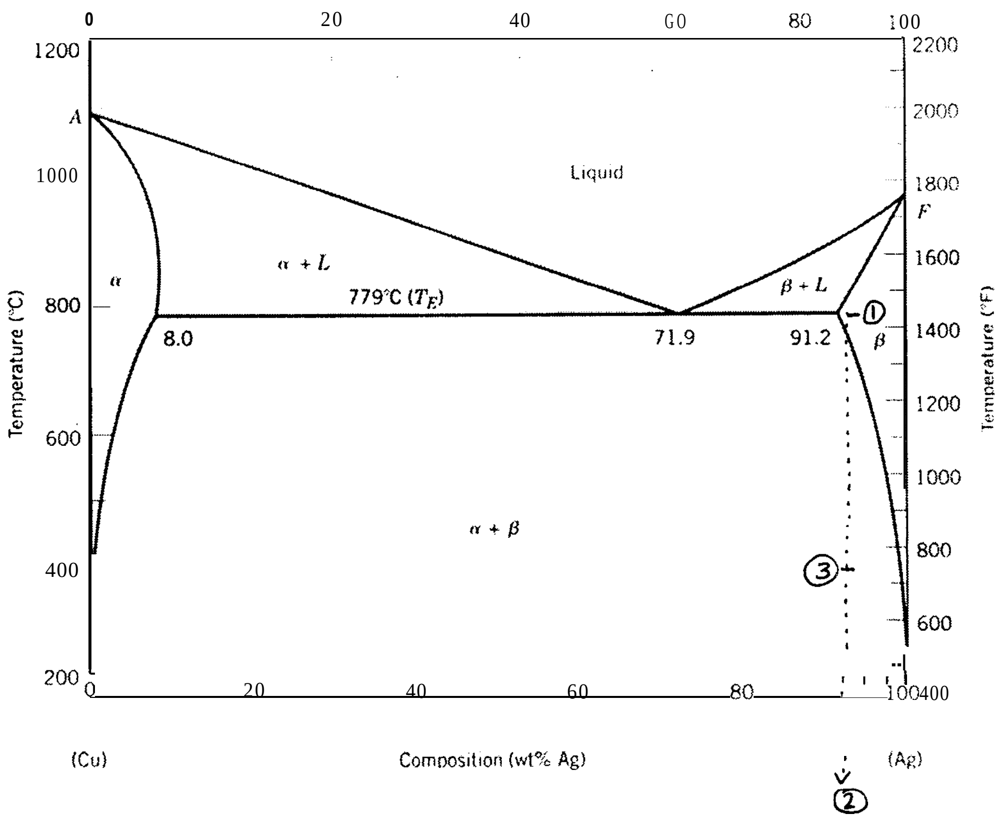
b. Explain your answer for part (a). [4]



SAMPLE C HAS THE SMALLEST GRAINS, SO THERE ARE MORE GRAIN BOUNDARIES TO STOP DISLOCATION MOTION ⇒ SLIP IS MORE DIFFICULT & HARDNESS AND STRENGTH ARE HIGHEST. STRENGTH IS GIVEN BY HALL-PETCH EQUATION:

$\sigma_y = \sigma_0 + \frac{k}{d^{1/2}}$, d = GRAIN SIZE

7. **Sterling silver has a composition of 92.5 wt.% Ag and 7.5 wt.% Cu. Sterling silver is often strengthened using age hardening, or precipitation hardening. Assume that you begin with a sample that has been slow cooled from the liquid region down to room temperature, and answer the following questions about precipitation hardening in the alloy.**



a. **List the three stages of the precipitation hardening heat treatment.** [3]

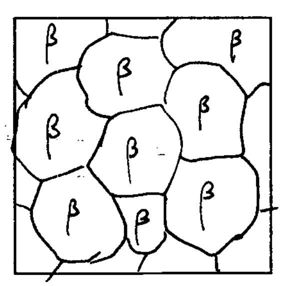
1. SOLUTIONIZING
2. QUENCHING
3. AGING

b. **Use the Ag-Cu phase diagram shown above to specify a temperature at which each stage of the precipitation hardening heat treatment could take place for the sterling silver alloy.** [3]

1. ABOUT 780°C
2. ROOM TEMP. (25°C) OR < 200°C
3. 300-600°C

c. **In the box below, sketch a picture of the Ag-Cu alloy after the first stage of the precipitation heat treatment. Label the phase or phases in your microstructure.** [3]

SINGLE PHASE SOLID SOLUTION (β)



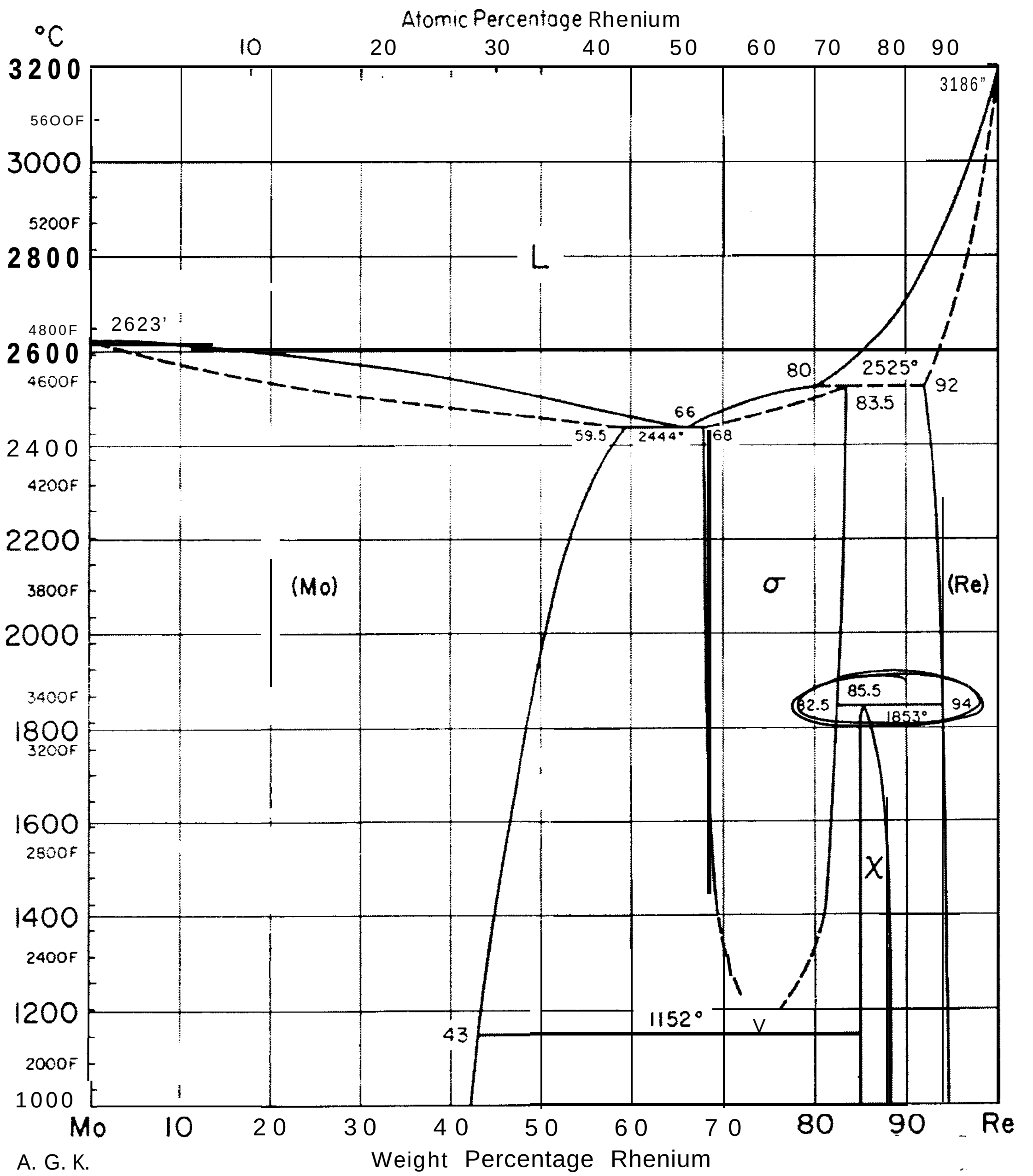
8. For each of the following, circle the material that will have the lower recrystallization temperature:

   a. 30% cold-worked stainless steel OR 60% cold-worked stainless steel [3]

   b. Stainless steel ($T_m \approx 1500$ °C) OR cartridge brass ($T_m \approx 1000$ °C). [3]

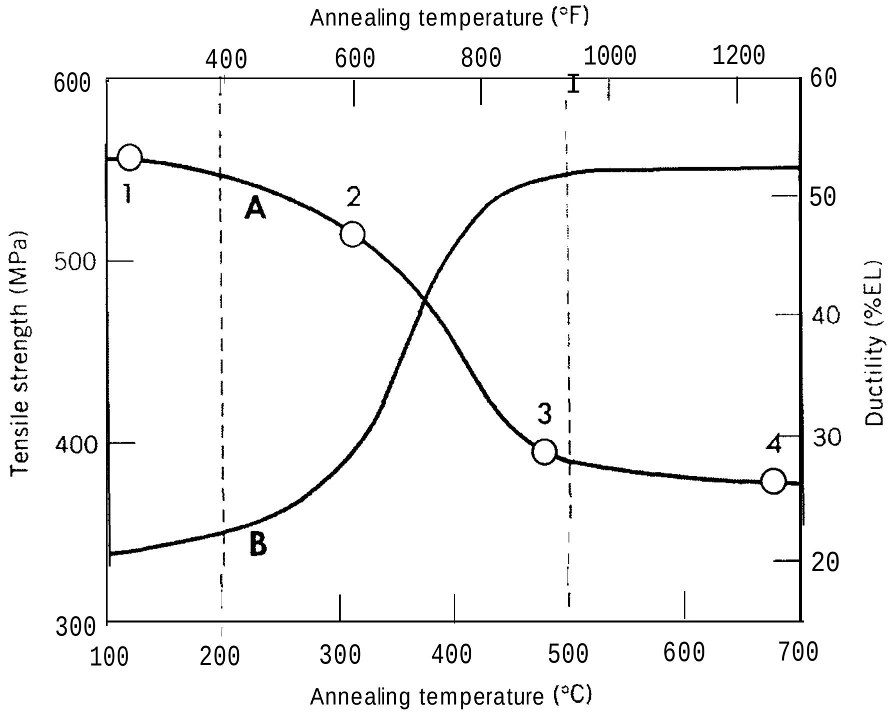
9. The molybdenum-rhenium phase diagram is shown below. Circle the peritectoid reaction on the phase diagram. [2]

Mo-Re Molybdenum-Rhenium



A. G. K.

10. Shown below is a graph of the effects of annealing temperature on the mechanical properties of brass. Assume the brass has a composition of 75 wt.% copper and 25 wt.% Zn.



a. Which curve, A or B, shows the changes in ductility during annealing? [3]

CURVE B

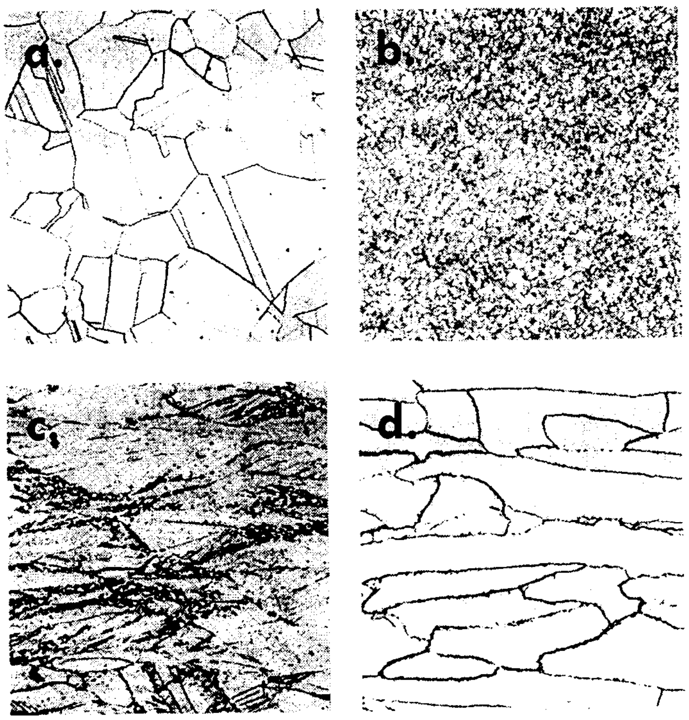
b. Several brass micrographs are shown below. Match each picture with the corresponding point (1, 2, 3, or 4) on the graph. [4]

D Point 1 on the graph

C Point 2 on the graph

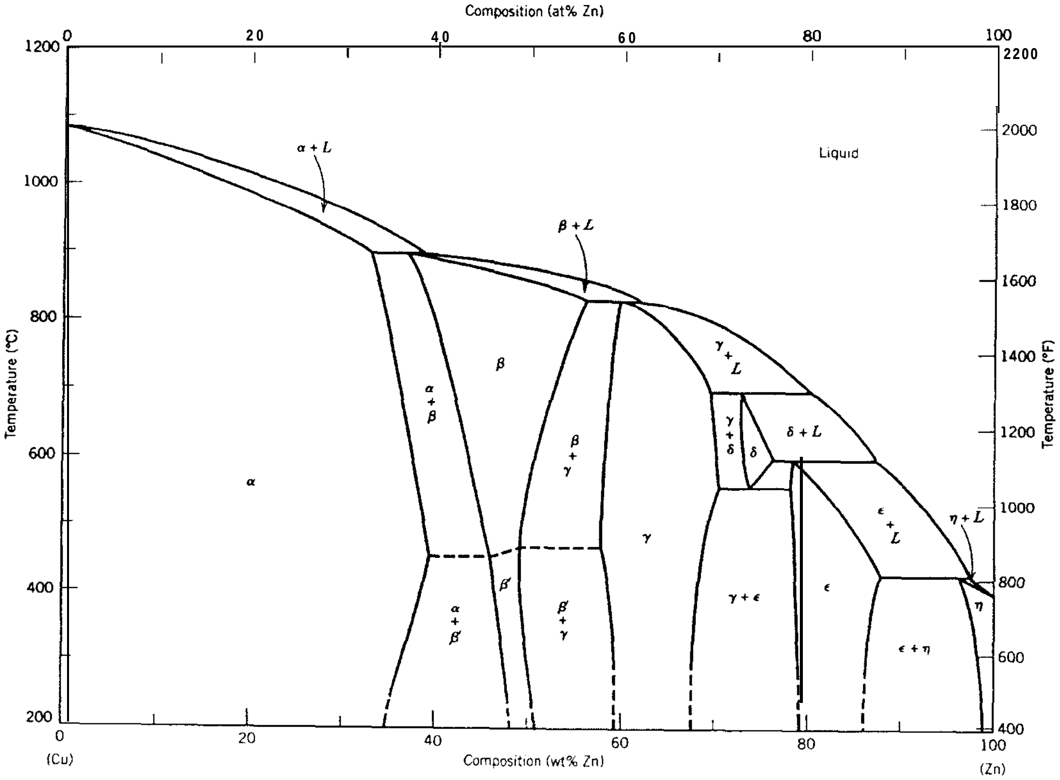
B Point 3 on the graph

A Point 4 on the graph



Problem 10 (continued) –

c. The phase diagram for Cu-Zn is shown below. Is precipitation hardening a possible strengthening mechanism in the 75% Cu, 25% Zn brass alloy (YES or NO)? Why or why not? [4]



NO. IT'S A SINGLE SOLID PHASE, SO NO PRECIPITATES WILL FORM.

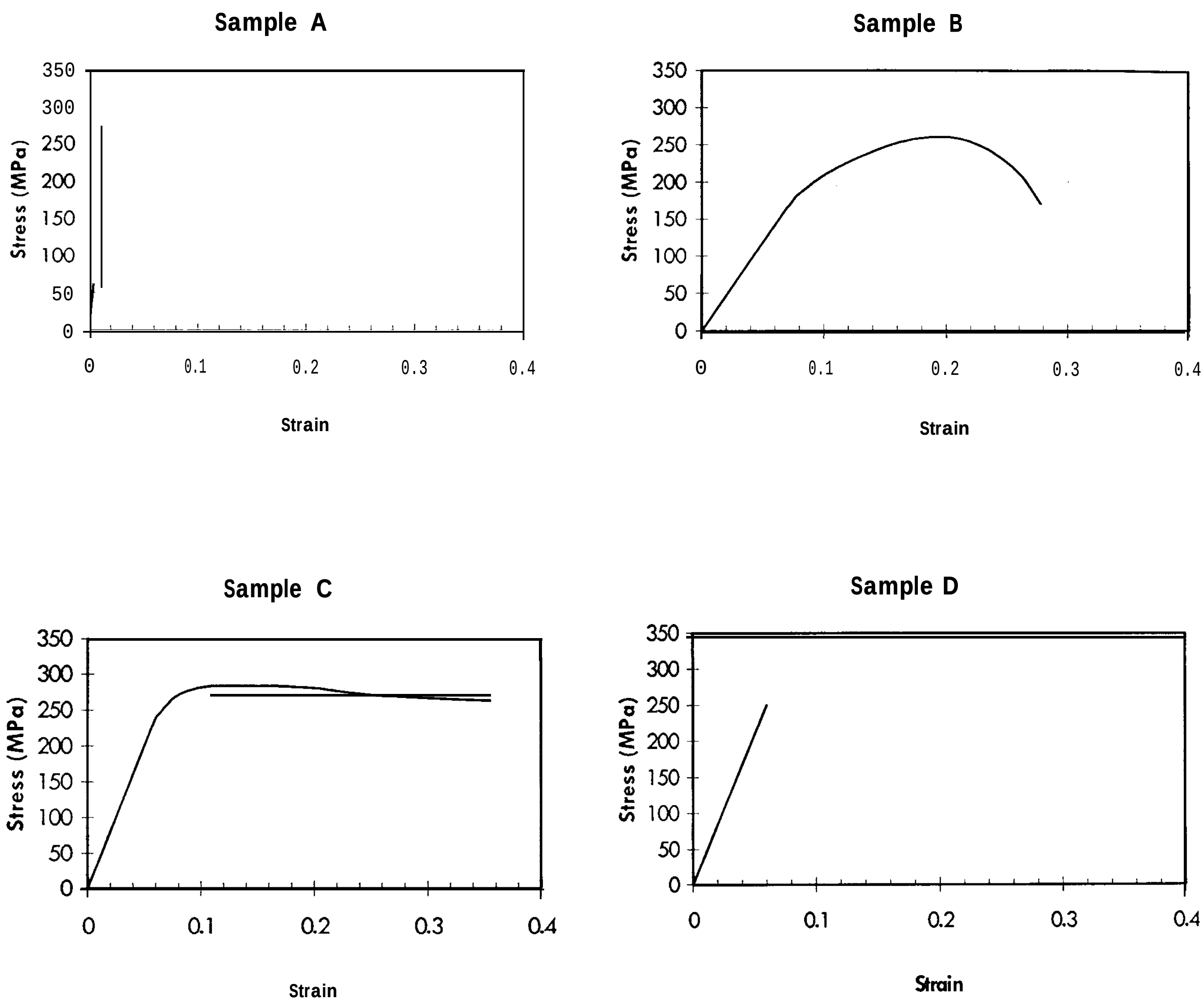


Figure 1. Stress-strain diagrams for Problem 1.

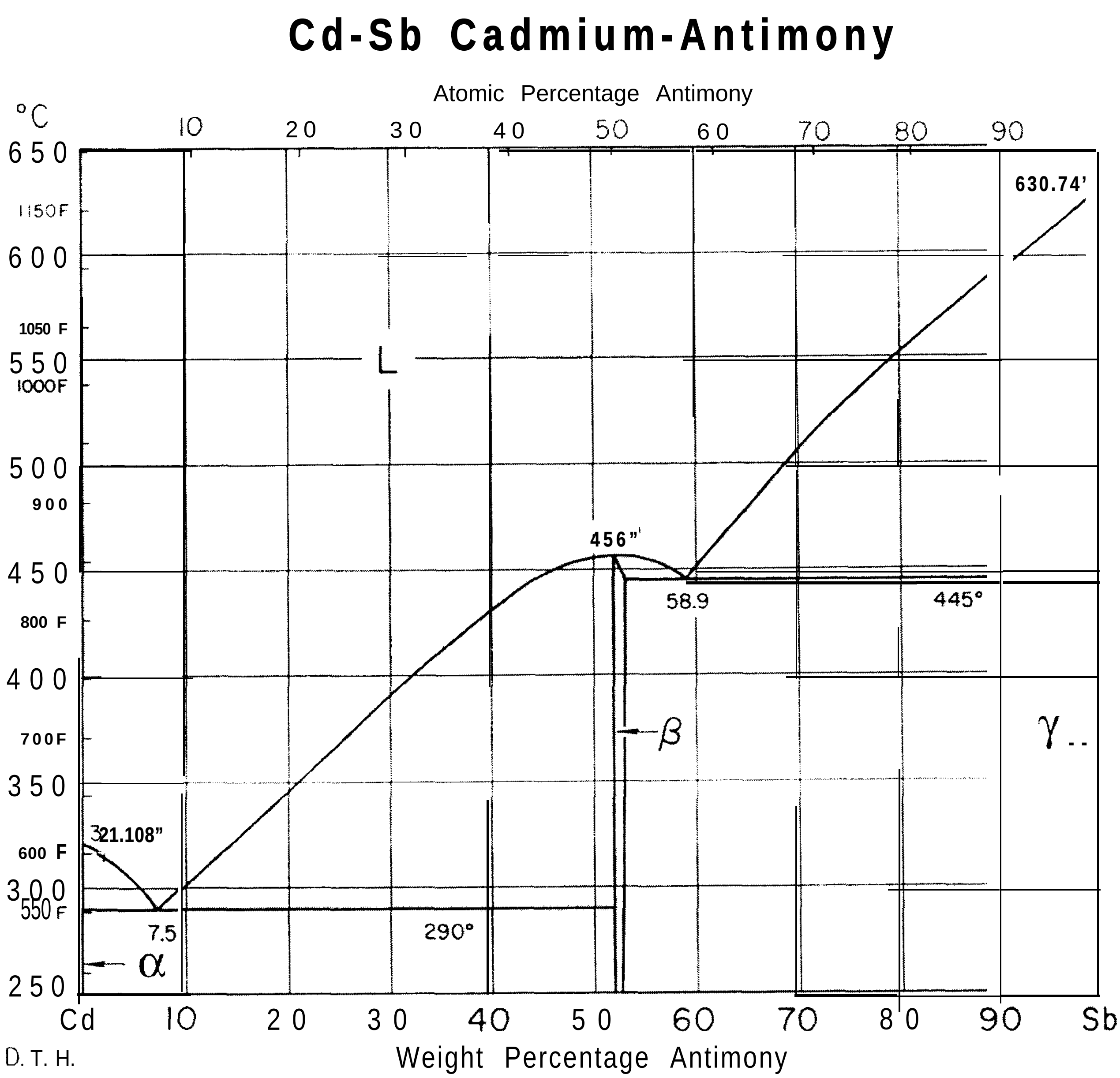


Figure 2. Phase diagram for Problem 2.