

## FINAL EXAMINATION

There are ten (10) questions. Please answer all questions. Answers to questions must be supported by evidence, either in the form of calculations or reasoning and logic. One word or single number answers will not be credited. All answers must be laid out in a logical manner that leads to an answer to the question. The answer must also be stated clearly.

Each question is worth 20 points for a maximum of 200 points.

There are two "Bonus Questions". Each is worth 5 points.

You are permitted to use your textbook, class notes, homeworks and homework solutions, and class handouts from this semester only. ***No other material may be used.***

You may work your answers for each question separately; however, when submitting your answers, please make sure that they are arranged sequentially, starting from No. 1. Answers that are included out of sequence will not be graded.

1. Please answer the following questions with respect to the Al-Mg phase diagram.
  - a. Label all the unlabeled regions in the phase diagram. *(4 points)*
  - b. Identify all three-phase invariant reactions. Please identify the temperature, composition and reaction. *(3 points)*
  - c. Identify the compounds or phases that will melt congruently. *(3 points)*
  - d. What is the maximum solid solubility of Al in Mg? *(2 points)*
  - e. What is the maximum solid solubility of Mg in Al? *(2 points)*
  - f. Identify all intermediate compounds or phases that are formed. *(3 points)*
  - g. Which intermediate compounds are stoichiometric compounds and which ones are non-stoichiometric compounds? *(3 points)*

2. Two friends are having a friendly argument. One friend asserts that there are compositional restrictions to the formulation of age-hardenable Al-Mg alloys, meaning that the Al-Mg alloys have to be within certain compositional ranges in order to be age-hardenable. The other friend states that all Al-Mg alloys are age-hardenable regardless of composition.
- Please state your thoughts and opinions, and substantiate them. *(5 points)*
  - Please suggest a processing sequence for producing an age-hardened Al-Mg alloy, i.e., one in which Al is the major component. *(5 points)*
  - What is the difference between a coherent precipitate and an incoherent precipitate? *(5 points)*
  - For your Al-Mg alloy, what would the precipitate be? *(5 points)*
3. Pure Al is frequently used as an electrical conductor. However, it is also extremely soft, lacking in strength. Your task is to strengthen the Al conductor by adding Mg, but making sure that the conductor you produce has only one phase.
- Describe how you might do this. *(4 points)*
  - Explain why adding Mg to the Al conductor would lead to an increase in strength. *(4 points)*
  - Would the conductor you produce have the same electrical conductivity as the pure Al conductor? *(4 points)*
  - Would it have the same elastic modulus as the pure Al conductor? *(4 points)*
  - Can you strengthen the pure Al conductor by some means other than alloying? Describe a simple process and any constraints that might apply. *(4 points)*
4. Pure Al is face centered cubic, with a lattice parameter of 4.049 Å.
- What is the coordination number? *(2 points)*
  - Which is the close packed plane? *(3 points)*
  - Which is the close packed direction? *(3 points)*
  - How many slip systems are available for this structure? *(3 points)*
  - What is the nearest neighbor distance? *(3 points)*
  - How many lattice points are there in each unit cell? *(3 points)*
  - What are the coordinates of the lattice points? *(3 points)*

5. A Mg alloy containing 20 wt % Al is first melted, held at 600°C, and then cooled slowly down to 100°C.
- Draw a cooling curve for this process. (4 points)
  - What are the phases that will be contained in this alloy at 100°C? (4 points)
  - How much of each phase will there be? (4 points)
  - What is the chemical composition of each phase? (4 points)
  - Draw a sketch of the microstructure that you would expect to see at room temperature. (4 points)
6. The oxide of aluminum,  $\text{Al}_2\text{O}_3$ , is commonly used as a thermal and electrical insulator.
- If  $\text{Al}_2\text{O}_3$  were to be contaminated by MgO, what type(s) of defects will result? (10 points)
  - How will these defects affect the diffusivity of oxygen through the  $\text{Al}_2\text{O}_3$ ? (10 points)
7. Aluminum is a strong oxidizer and oxidizes very easily - more so than mild steel. Yet we are able to use aluminum for a variety of applications without having to worry about the formation of rust or similar oxides like in the case of mild steel. Please explain why. (20 points)
8. Two scientists are conducting some diffusion experiments. Their first experiment is with Cu and Ni and they find that Cu diffuses into Ni and vice versa, i.e., Ni diffuses into Cu as well. Their second experiment is with Al and Sn. To what extent do you think Al will diffuse into Sn, and will Sn diffuse into Al? (20 points)
9. You have two Al single crystals, at room temperature. One has the (111) orientation and the other has the (110) orientation. You place a drop of DI water on each of these and measure the contact angle. What would the relative magnitude of the contact angles be? (20 points)

10. You are commissioned with the task of sintering an  $\text{Al}_2\text{O}_3$  disk that is 1 mm thick and 5 mm in diameter. You find that you have a choice of using one of two powders, one which has a mean particle diameter of 1  $\mu\text{m}$  and another which has a mean particle diameter of 7  $\mu\text{m}$ . If cost were not an issue, which powder would you choose. (20 points)

### **BONUS QUESTIONS**

1. In the past a very well known female scientist received two Nobel Prizes - one for chemistry and one for physics. What is her name?
2. What is the name of the largest public library in the western U.S.A.?