ORDRE DES INGÉNIEURS DU QUÉBEC

FALL 2014 SESSION

Open-book examination
Calculators: only authorized models
Duration: 3 hours

14-MT-A4 STRUCTURE OF MATERIALS

Please, answer all questions.

Question 1. (2 points)

What is the Hall-Petch relationship and to what does it relate?

Question 2. (4 points)

What are the differences in the micro-mechanism of elastic and plastic deformation?

Question 3. (2 points)

What is the atomic packing factor?

Question 4. (2 points)

Why do polycrystalline materials have isotropic properties?

Question 5. (12 points)

What are the four strengthening mechanisms available to increase the strength of metals, and describe the process?

Question 6. (4 points)

What is recrystallization, and why does it occur?

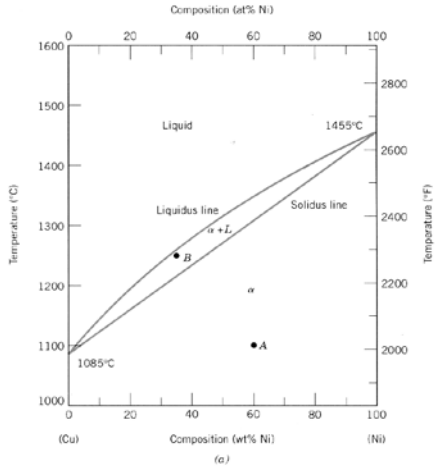
Question 7. (5 points)

What type of microstructure would you like to have for a material that must survive long term exposure to high temperature?

Question 8. (4 points)
What are the differences between substitutional and interstitial atoms?

Question 9. (5 points)

Describe and draw the microstructure evolution during the solidification of a Cu-35Ni alloy.



Question 10. (10 points)

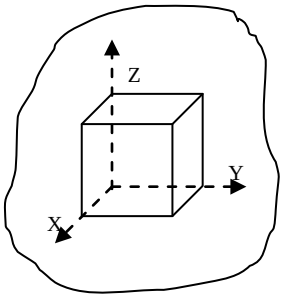
For two elements, A and B, that are ionically bonded, the attractive and repulsive energies EA and ER (in electron volts per A-B pair) depend on the distance (r in nanometers) between the two resulting ions, as follows:

$$E_A = \frac{-1.32}{r} \quad \text{et} \quad E_R = \frac{6.55 \bullet 10^{-6}}{r^8}$$

Determine the equilibrium distance for the two elements and the force required to break the bond.
1eV = $1.6X10^{-19}$ J

Question 11. (10 points)

You are looking at the side view of a crystal of Ba (BCC). A tensile stress parallel to the [001] direction is imposed on the crystal. Determine the slip system that will be active during the deformation of the crystal. Calculate the stress required to initiate plastic deformation in the crystal (τ_{crss}: 5 MPa).



Question 12. (4 points)

What characteristics decide if the solute atoms will form a solid solution or a second phase in the solvent?

Question 13. (2 points)

List the members of the {110} family of planes in the cubic system.

Question 14. (6 points)

Complete the following table.

Definition	Answer
The regular geometrical arrangement of points in crystal space	
One component or element of a solution present in a minor concentration. It is dissolved in the solvent.	
An individual crystal in a polycrystalline metal or ceramic	
The fractional change in length divided by the change in temperature	
A coulombic inter-atomic bond that exists between two adjacent and oppositely charged ions	
A normally occupied lattice site from which an atom or ion is missing	

Question 15. (3 points)

Draw and label on the same graph schematic engineering stress strain curves for materials with the following sets of properties:

1. A material with a high elastic modulus, high strength and no ductility
2. A material with high elastic modulus equal to that in (a), but with half the strength and with high ductility.
3. A material which does not work harden but which has high ductility.

Question 16. (5 points)

Boron has a much lower coefficient of thermal expansion than aluminum, even though both are in the 3B column of the periodic table. Explain, based on binding energy, atomic size and the energy well, why this difference is expected.

Question 17. (15 points)

Two pure metals, A and B, melts at 650^{o}C and 320^{o}C, respectively. An intermetallic compound A_2B melts at 550^{o}C. The intermetallic contains 80wt%B. In addition, the following two reactions were observed:

$$L(70wt\%B) \rightarrow A\ (30wt\%B) + A_2B \text{ occuring at } 450^{o}C$$
$$L(90wt\%B) \rightarrow B\ (5wt\%A) + A_2B \text{ occuring at } 300^{o}C$$

1. Draw the phase diagram

2. Draw the final microstructure at room temperature if an alloy 50-50 is slowly cooled down from 700^{o}C. How would look like the microstructure if the same alloy is rapidly cooled down? Write in bullet format the main differences between both microstructures.

3. For an alloy 60wt%A-40wt%B at 449^{o}C, what are the 2 phases present, what are there proportions and compositions.

Question 18. (5 points)

Describe the Frank-Read mechanism for the development of dislocations.