Ph.D. Qualifying Examination

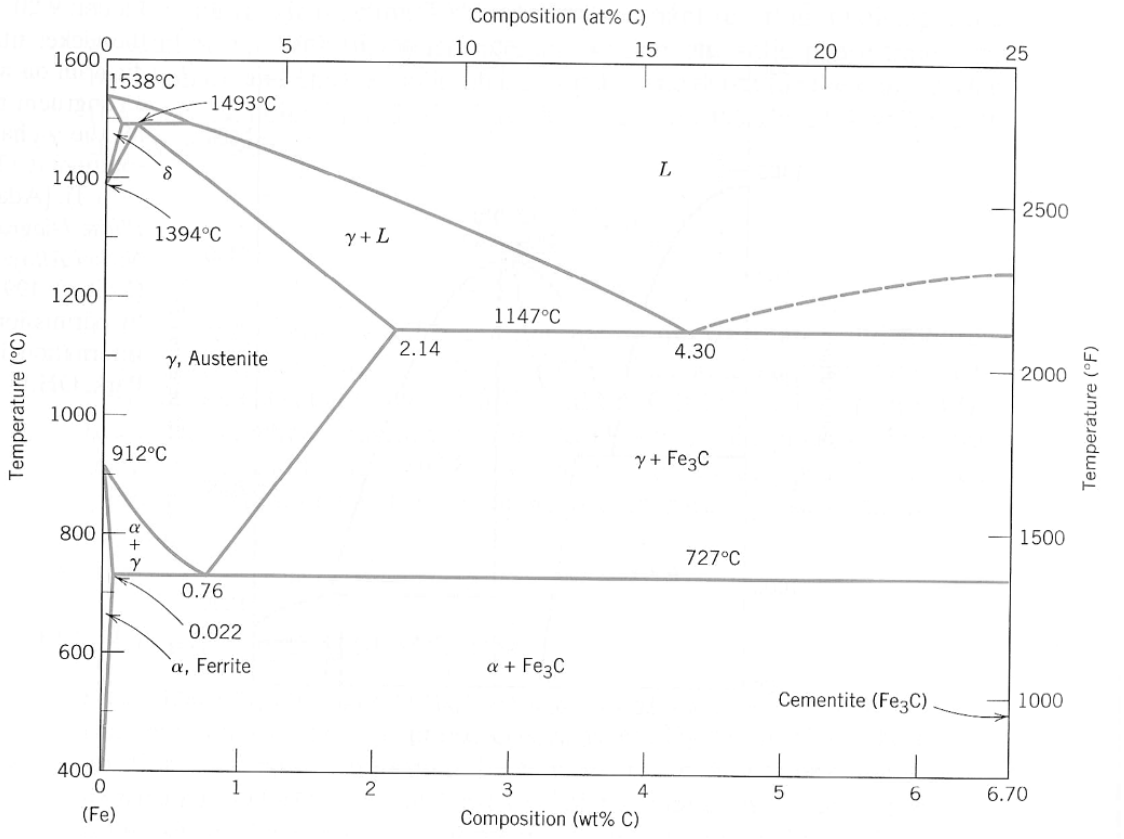
Materials Science

Spring 2019

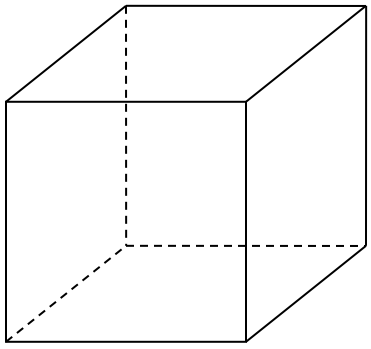
Notes:

- There are a total of 5 problems.
- Time allowed: 2.0 hours.
- Exam is closed book and closed-notes (one sheet of formulas is allowed)
- Each problem may have a different weight (total=100 points).
- Show your work on these exam sheets. (Add additional sheets, if needed.)
- You may use a calculator.
- Laptops and cell phones are not allowed.

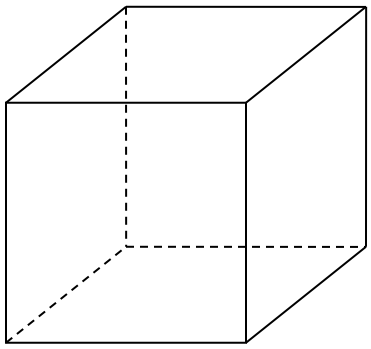
1. Consider the Fe-C phase diagram. (30 points)
   (a) What is the maximum possible solid solubility of carbon atoms in iron throughout the entire temperature range?
   (b) An Fe-C alloy containing 0.5 wt% carbon is slowly cooled from 1000°C down to room temperature. Do you expect proeutectoid cementite to form during the process? Why or why not?
   (c) Sketch the microstructure of the alloy in (b) at room temperature.



2. (a) Lithium fluorite (LiF) has the so-called "rock salt" crystal structure, which may be thought of as two interpenetrating FCC lattice, one composed of the cations, the other of anions. Draw the atomic arrangement in a single *unit cell* shown below, using "O" for F and "•" for Li. Also, what type of the atomic bond does this LiF possess? (10 points)



(b) Silicon carbide (SiC) has the so-called "zinc blende" crystal structure, in which one type of atom forms an FCC-like structure while the other occupying certain interior tetrahedral positions. Draw the atomic arrangement in a single *unit cell* shown below, using "O" for Si and "•" for C. Also, what type of the atomic bond does this SiC possess? (10 points)



3. True or False? (2.5 points each)

____When the concentration of solute in a solid solution exceeds its solubility limit, a new solid solution or phase forms that has a composition distinctly different than the original solid solution.

____On the basis of specific (per weight) strength, aluminum alloys are stronger than steel alloys.

____All ferrous alloys have similar microstructures.

____During a quenching treatment, it is possible to cool the specimen at a uniform rate throughout the entire piece.

____Laminated composites have high strengths in all directions (in three dimensions).

____A brittle material typically exhibits substantial plastic deformation with high energy absorption before fracture.

____The properties of non-crystalline materials are anisotropic.

____It is possible to produce a perfectly crystalline solid that does not contain any vacancies.

4. You are asked to design a structure that requires a material with a tensile elastic modulus of 300 GPa and a tensile strength of 1000 MPa. What is your material of choice if: [Justify your answers] (15 points)

a) It should withstand high temperatures (1500 °C) and is tough?

b) The service temperature is only 100°C and the part has to be lightweight.

5. a) What are the different inter-atomic bonding types? (5 points)

b) What are the bonding types in ceramics, polymers, and metals? (5 points)

c) How do the elastic modulus and melting temperature in these material classes (metals, polymers and ceramics) depend on these bonding types? (5 points)