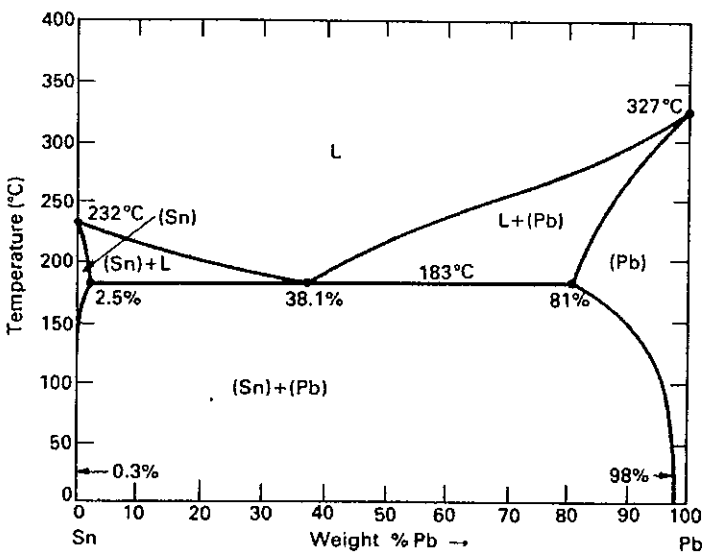
1. (8 points)

The phase diagram for the lead–tin alloy system is illustrated in the following, and there are three phases: L – a liquid solution of lead and tin; (Pb) – a solid solution of tin in lead; and (Sn) – a solid solution of lead in tin.

For an alloy of overall composition 50 wt% lead at 170°C, what is equilibrium constitution of our alloy?

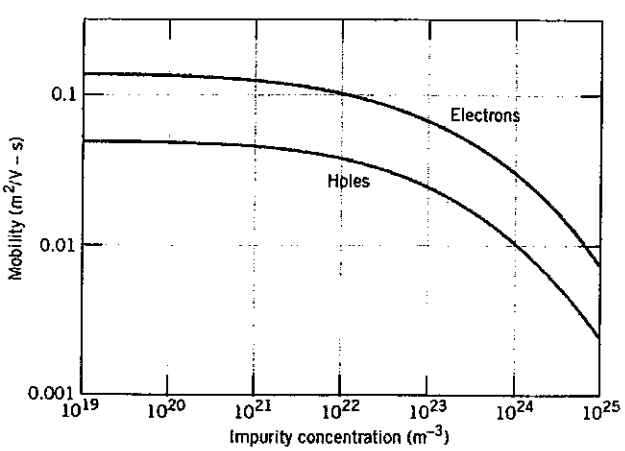


2. (7 points)

For silicon, dependence of room temperature electron and hole mobilities (logarithmic scale) on dopant concentration (logarithmic scale) is shown in the following diagram. To high-purity silicon is added 10^{23} m^{-3} arsenic atoms.

(a) Is this material *n*-type or *p*-type? (3 points)

(b) Calculate the room-temperature electrical conductivity of this material. (4 points)



3. (10 points)
For the homogeneous nucleation of a spherical solid particle in a liquid, derive the critical radius of a stable solid particle nucleus and the activation free energy in terms of volume free energy and surface free energy, and describe the physical meaning of them.

4. (10 points)
At room temperature the electrical conductivity of PbS is 25 $(\Omega\text{-m})^{-1}$ whereas the electron and hole mobilities are 0.06 and 0.02 $m^2/V\text{-s}$, respectively. Compute the intrinsic carrier concentration for PbS at room temperature.

5. (15 points)
(a) If a rod of brass 0.35 m long is heated from 15 to 85 °C while its ends are maintained rigid, determine the type and magnitude of stress that develops. Assume that at the rod is stress free.
(b) What will be the stress magnitude if a 1 meter long rod is used?
(c) If the rod in part (a) is cooled from 15 °C to -15 °C, what type and magnitude of stress will result? (The modulus of elasticity of brass is 97 GPa; the thermal expansion coefficient of brass is 20.0×10^{-6} $(°C)^{-1}$)

6. (15 points) Crystal Structure
Please draw crystal structure of the following compound and list the coordination number of cation and anion ions
(a) MgO
(b) ZnS
(c) $BaTiO_3$ (Pervoskite)

7. (10 points)
As the CaO was added as an impurity to Li_2O, what kind of defects would be produced to keep electroneutrality ? If LiCl was used as an impurity, what is the major defect?

8. (15 points)

A continuous and aligned fiber-reinforced composite is to be produced consisting of 45 vol% aramid fibers and 55 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are as follows:

	Modulus of elasticity (GPa)	**Tensile strength (MPa)**
Aramid fiber	131	3600
Polycarbonate	2.4	65

Also, the stress on the polycarbonate matrix when the Aramid fibers fail is 35 MPa.

For this composite, please compute

(a) The longitudinal tensile strength, and (7 points)

(b) The longitudinal modulus of elasticity (8 points)

9. (10 points)

In the following pair of polymers, which one has higher thermal conductivity? Why?

(a) linear polyethylene *vs* lightly branched polyethylene

(b) alternating poly(styrene-butadiene) copolymer *vs* random poly(styrene-butadiene) copolymer