

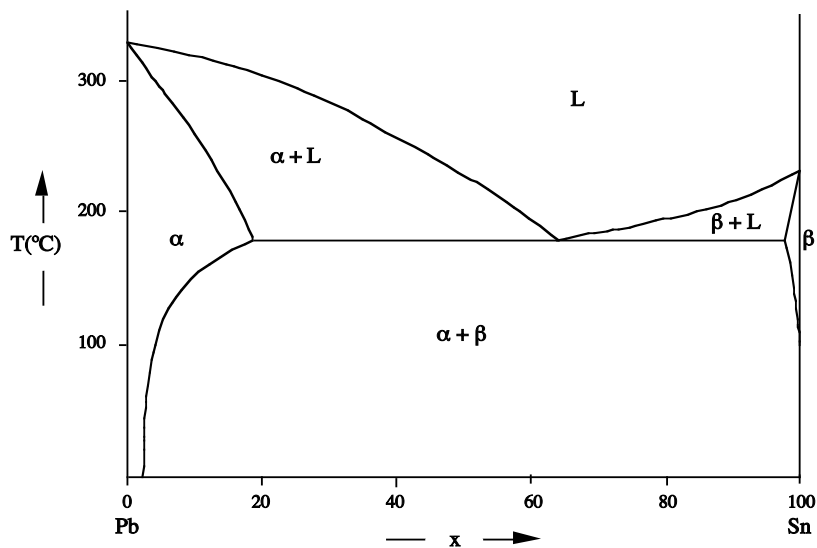
Engineering 45 Final Examination May 21, 2002

Problem 1: (20 points)

A compound has the composition AB, and, at room temperature, has the NaCl crystal structure. Provide brief explanations for the following.

- Both ionic and metallic bonding are compatible with this structure.
- If the material is transparent, it must be ionic.
- On increasing the temperature, T , the electrical conductivity increases if the material is ionic, but decreases if it is metallic.
- If the compound is metallic its conductivity decreases when a small amount of solute is added, whatever the nature of the solute.
- While some compounds with the NaCl structure are metallic (for example, TiC and TiN), very few compounds of two metallic elements have the NaCl structure.

Problem 2: (15 points)



The phase diagram of the Pb-Sn binary system is shown above.

(a) As reflected in the phase diagram, Pb and Sn can form solutions at all compositions in the liquid state, but not in the solid state. Why?

(b) The solubility of Sn in the Pb-rich α phase increases with temperature (at least at low temperature). Why would you expect this?

(c) Suppose you are given a sample that has composition 20Sn-80Pb, but need a sample that has precisely the eutectic composition. How could you obtain it?

Problem 3: (20 points)

Briefly explain the following:

(a) Gold, aluminum and chromium are widely used for their corrosion resistance. The oxides of gold are thermodynamically unstable at room temperature, but Al and Cr are among the strongest oxide formers known. So how can they be stable?

(b) A solid piece of iron will not oxidize spontaneously at room temperature even if it is put into pure oxygen. Similarly, Fe will not rust when put into pure water. But if Fe is put into water than contains a little bit of dissolved oxygen, it begins to rust almost immediately. Why?

(c) If a piece of Fe is plated with Au over part of its surface, there is no particular reaction. But if the partially plated Fe is placed in tap water, the iron corrodes rapidly. Why does Au attack Fe in water?

(e) If Cr is added to Fe, and the alloy is put in in water, there is no great effect on the corrosion rate until the Cr content exceeds about 8 atom percent. At that point, suddenly, the rate of corrosion drops to almost zero. Since the alloy is still almost entirely Fe, why doesn't it rust?

Problem 4: (20 points)

(a) Draw a simple sketch of the band diagrams of an n-type and a p-type semiconductor. Indicate the position of the Fermi level relative to the center of the band gap in each material at moderate temperature.

(b) If the semiconductor is Si, what elements might you choose for the donor and acceptor? Why?

(c) Draw the band diagram of an n-p-n bipolar transistor, showing the approximate position of the Fermi level through the device.

(d) Given that a p-n junction in reverse bias cannot conduct a significant current, how is it that an n-p-n junction can conduct current when a positive voltage is imposed on the thin p-layer?

Problem 5: (15 points)

(a) List four different mechanisms for hardening a metal and briefly explain why each works.

(b) Aluminum alloys are only about one-third as strong as steels that have similar microstructures. Why would you expect this?

(c) What is the mechanism that determines the ultimate tensile strength of a ductile metal?

Problem 6: (10 points)

While on a well-deserved winter vacation at Tahoe, Alvin Underfoot, a random undergraduate, was startled awake by screams from an adjoining cabin. He dashed over, arriving at the same time as several other vacationers and a team of police, who had happened to be driving by. A young man was sitting in a chair, sobbing. A young lady, also distraught, was comforting him. On the floor was a second young lady, dead, with the broken blade of a steak knife protruding from her chest.

"He killed my wife", the man said between sobs. "When we came back to the cabin, me, my wife and her friend Suzy (indicating the other lady) we surprised him here. He must have been a robber. When we opened the door he grabbed a steak knife from the kitchen alcove and stabbed her. Then he ran away. The knife broke and he took the hilt with him. If you hurry you may catch him."

While the police tried, sympathetically, to calm the man down and get a description of the murderer, Alvin eyed the broken blade suspiciously. He then wandered over to the kitchen alcove and took an identical steak knife from the set. He bent it almost into a right angle, then straightened it out again. He then stepped outside, immersed it in the snow, then bent it again until it snapped in two.

"This man is not telling the truth," Alvin announced. "The woman was, in fact, killed outside, almost certainly by these two dubious creatures, and her body carried in here. If you investigate the surrounding woods, I am certain you will find a fresh pile of snow concealing a pool of this poor woman's blood. And if you search a bit further, you will find the hilt of the knife with this evil person's fingerprints all over it."

Alvin was quickly proved right on both counts. The couple confessed. It seems that the betrayed wife had discovered them making serious whoopee in the woods, whereupon the husband had stabbed her with the steak knife he had brought to immortalize the site by carving his new girlfriend's initials into a local tree.

How did Alvin know?