Chapter 1 Homework Solutions

1. For a face centered cubic lattice of identical atoms, with a lattice constant of 4.5 Å, find the following:

   a. Maximum packing fraction.

   The face centered cube has 4 equivalent atoms ($1/8^{th}$ times 8 corners + ½ each times 6 faces). Therefore the packing factor is the volume of 4 atoms divided into the volume of the unit cell. The unit cell volume is simply a^3 or 91.125 Å^3.

   Using the formula for the volume of a sphere, $V = \frac{4}{3}\pi r^3$, and the atomic radius r of 1.59 Å (from part b. of this problem), we calculate the volume of the 4 atoms to be $V = (4)\frac{4}{3}\pi(1.59\text{Å})^3 = 67.35\text{Å}^3$.

   Thus the packing factor is $P.F = \frac{67.35}{91.125}\text{Å}^3 = 74\%$

   b. Radius of atoms treated as hard spheres.

   The hard sphere model would line up 3 atoms along the face diagonal of the cube, with the end two extending only one radius into the cube's face. Thus the face diagonal would equal 4 atomic radii in length (one each from the corner atoms, and two radii from the center face atom). Applying Pythagoras' theorem; $a^2 + b^2 = c^2; a^2 + a^2 = (4r)^2$ or $4r = \sqrt{2a^2}$ thus $r = \frac{\sqrt{2}}{4}a$. We find that r is 1.59 Å.

2. A Si crystal is to be grown by the Czochralski method, and is desired to contain $1.7*10^{16}$ Boron atoms per cm^3. Presuming a k_d of 0.28, how many grams of Boron must be added to the 10 *kg* Si melt to obtain this Boron concentration? [Hint: Example 1-4, p 17]

   If only 28% of the Boron moves from the liquid to the solid, and we want $1.7*10^{16}$ Boron atoms per cm^3 in the solid, we must start with $1.7*10^{16}/0.28$ atoms per cm^3 in the liquid melt. So our melt must contain $6.07*10^{16}$ Boron atoms per cm^3.

   Using the density of Si of 2.33 g/cm^3, we calculate that 10*kg* of Si will have a volume of 4992 cm^3. That much Si will require $(4992)(6.07*10^{16}) = 2.6*10^{20}$ Boron atoms.

   $2.6*10^{20}$ Boron atoms weigh ($2.6*10^{20}$ Boron atoms)*(10.8 g/mole of Boron)/$6.0*10^{23}$ atoms/mole = $4.664*10^{-3}$ grams or 4.664 milligrams of Boron

3. Problem 1.16, p27.

   The sketch should look something like that in figure 1-8a. The assignment was just to force you to think about it.