Homework Assignment #3

(due 10/1/14) Physics 601

Reading: (i) Simon (S) chapters5 - 7, 12 (ii) Alloul (A) 2.1, (iii) "Impossible Crystals," by H. C. von Bayer, Discover (1990) (iv) A.I. Goldman et al. "Quasicrystalline Materials," American Scientist (1996) (v) P.J. Steinhardt, "Icosahedral Solids: A New Phase of Matter?" Science (1987) (vi) P.J. Lu and P.J Steinnardt, "Decagonal and Quasi-Crystalline Tilings in Medieval Islamic Architecture," Science (2007). (please find these readings on the course website)

Problems:

1. Simon Problem 4.5 Chemical Potential of 2D Electrons

2. Simon Problem 5.1 Madelung's Rule.

3. Simon Problem 6.1 Chemical Bonding

4. Cohesive Energy of Free Electron Fermi Gas

. *Cohesive energy of free electron Fermi gas.* We define the dimensionless length r_s as r_0/a_H, where r_0 is the radius of a sphere that contains one electron, and a_H is the Bohr radius $\hbar^2/e^2m$. (a) Show that the average kinetic energy per electron in a free electron Fermi gas at 0 K is $2.21/r_s^2$, where the energy is expressed in rydbergs, with 1 Ry $= me^4/2\hbar^2$. (b) Show that the coulomb energy of a point positive charge e interacting with the uniform electron distribution of one electron in the volume of radius r_0 is $-3e^2/2r_0$, or $-3/r_s$ in rydbergs. (c) Show that the coulomb self-energy of the electron distribution in the sphere is $3e^2/5r_0$, or $6/5r_s$ in rydbergs. (d) The sum of (b) and (c) gives $-1.80/r_s$ for the total coulomb energy per electron. Show that the equilibrium value of r_s is 2.45. Will such a metal be stable with respect to separated H atoms?

5. Hcp structure

Hcp structure. Show that the c/a ratio for an ideal hexagonal close-packed structure is $(\frac{8}{3})^{\frac{1}{2}} = 1.633$. If c/a is significantly larger than this value, the crystal structure may be thought of as composed of planes of closely packed atoms, the planes being loosely stacked.

6. Please sketch a rectangular lattice with $a_2/a_1 = 2$. On this sketch please indicate a pair of neighboring planes of each type: (0,1), (1,2), (2,3), (1,2).

Questions:

7. What are quasicrystals? Please use a minimum of three sentences in your response.
8. Please explain why the initial discovery of quasicrystalline materials was met by disbelief Among many in the soild state and crystallographic communities. Please use a minimum of three sentences in your response.
9. Please describe ways in which the diffraction pattern of a quasicrystsal is similar and different to that of a conventional crystal.
10. Please describe two physical properties of quasicrystals that differ from those of their crystalline counterparts.
11. Please describe two possible applications of quasicrystals.
12. Please explain the challenges of distinguishing a quasicrystal from an icosahedral glass.