Material Science
EXAM I

Nov. 12, 2012

I. Explain the following terms: (24%)

1. Graphene（石墨烯）
2. Composite Material
3. Nanomaterial
4. Electronegativity
5. Electric dipole moment
6. Crystal
7. Atomic Packing Factor (APF)
8. <100>
9. Nucleation
10. Equiaxed Grain
11. metal alloy
12. Grain Boundary

II. Short answer: (45%)

1. What are two types of solid solutions?
2. Why is the atomic packing factor of diamond smaller than those of metals?
3. What are the main classes of engineering materials?
4. Describe the factors that control packing efficiency (number of neighbors) in ionic solids.
5. What are the crystallographic directions of a family or form? What generalized notation is used to indicate them?
6. During solidification, how does the degree of undercooling affect the critical nucleus size? Assume homogeneous nucleation.
7. How can the grain size of a cast ingot be refined?
8. Using the data in the following table, predict which one has the higher degree of atomic solid solubility of the following two elements in iron: (*a*) Chromium, (*b*) Titanium

Element	Atom radius (nm)	Crystal structure	Electro-negativity	Valence
Iron	0.124	BCC	1.7	+2, +3
Chromium	0.125	BCC	1.6	+2,+3,+6
Titanium	0.147	HCP	1.3	+2, +3, +4

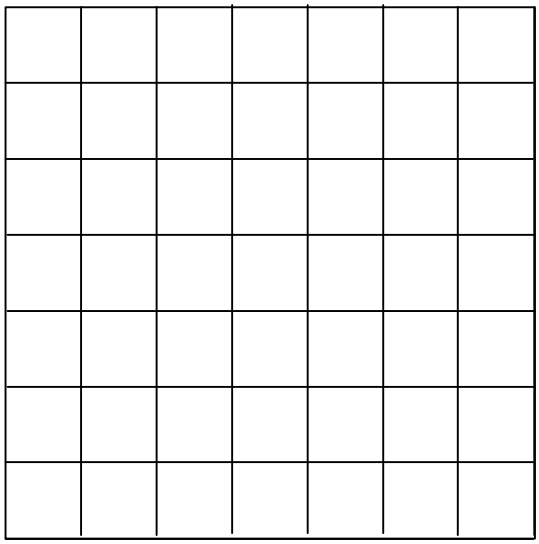
9. There are six complete atoms per HCP unit cell. Actually, how many atoms are partially involved in a HCP unit cell? How do you count the number of the atoms in the unit cell?
10. What does it mean that the noble gases can solidify?
11. Would you expect non-crystalline materials to have grain boundaries? Why or why not?
12. Which one has the higher melting point, Cu or Ag? Why?
13. A good approximation of the energy of the hydrogen electron for allowed energy levels is the Bohr equation

$$E = -\frac{13.6}{n^2}\ \text{eV}$$

What is ionization energy of the hydrogen electron? Why?

14. What does "benzene ring" mean?
15. What are the conditions favorable for extensive solid solubility of one element in another?

III. Determine, by counting, the ASTM grain-size number of the virtual microstructure shown in the following figure. This micrograph is at 100x with the area of one square inch. Assume that each small square is a grain. (5%)

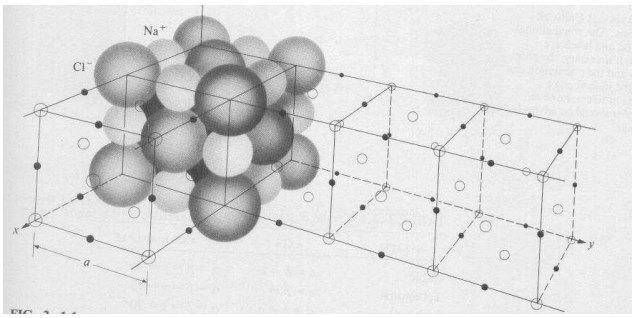


IV. Determine the packing factor and density of sodium chloride (NaCl). (9%)
The atomic mass of sodium is 22.99 g/mole and 35.45 g/mole for chlorine.

r_{Na} = 0.97 Å, r_{Cl} = 1.81 Å, Avogadro number is 6.02 x 10^{23} atoms/mole.

Hint:

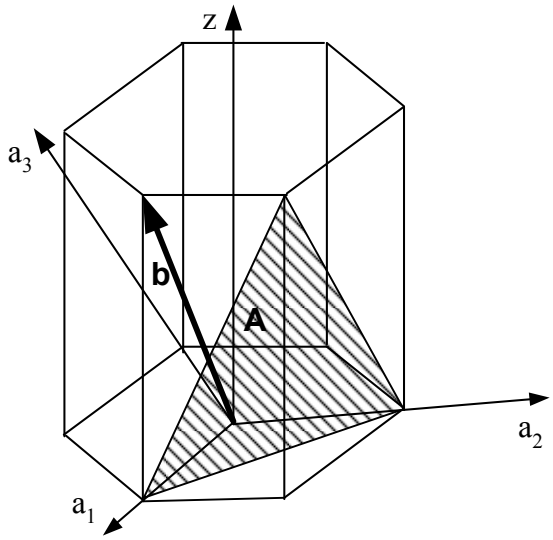
1. Packing factor = $\frac{\text{volume of Na atoms + volume of Cl atoms}}{\text{volume of unit cell}}$
2. The unit cell is cubic, there are four Na atoms and four Cl atoms per unit cell and a = $2\times(r_{Na} + r_{Cl})$.



V. (a) Consider iron below 912 °C, where its structure is BCC. Given the density of iron as 7.86 g cm^{-3} and its atomic mass as 55.85 g/mol, calculate the lattice parameter of the unit cell (i.e., the length of the cube edge, a) and the radius of the Fe atom. (8%)

(b) At 912 °C, iron changes from the BCC (α-Fe) to the FCC (γ-Fe) structure. The radius of the Fe atom correspondingly changes from 0.1258 nm to 0.1291 nm. Calculate the density of γ-Fe and explain whether there is a volume expansion or contraction during this phase change. (6%)

VI. What are the indices of the direction vector b and plane A shown in the following figure? (8%)



VII. An x-ray diffractometer recorder chart for an element that has either the BCC or the FCC crystal structure showed diffraction peaks at the following 2θ angles: 40°, 58°, 73°, and 86.8°. (Wavelength λ of the incoming radiation was 0.154 nm.)

(a) Determine the crystal structure of the element. (4%)

(b) Determine the lattice constant of the element. (4%)

(c) Identify the element. (2%)

$$\sin^2\theta = \lambda^2\left(h^2 + k^2 + \ell^2\right)/(4a^2)$$

FCC: (111), (200), ...; BCC: (110), (200), ...

	element	a (nm)
1	copper	0.36147
2	gold	0.40788
3	nikel	0.35263
4	iridium	0.38389
5	lead	0.49502
6	tungsten	0.31648