EMA 5104 Homework #2
Due on Friday, Sep 25th at 11:59pm

1. Determine the structural factor for an FCC structure.

2. Monochromatic x-radiation having a wavelength of 0.0711 nm was used in an XRD experiment of an unknown metal. The diffraction angles (2θ) for the first four peaks are found at 20.1°, 28.5°, 35.1°, and 40.7°.
   (a) Determine whether this metal's crystal structure is FCC or BCC. Explain the reason for your choice.
   (b) Index (i.e., give h, k, and l indices) each of these peaks.
   (c) Determine the lattice constant, a. What metal is this?
   (d) Calculate the interplanar spacing for each of these peaks.
   (e) Determine the atomic radius of this metal.

3. Calculate the number of vacancies per cubic meter in iron (Fe) at 900°C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm^3 (at 900°C) and 55.85 g/mol, respectively.

4. Atomic radius, crystal structure, electronegativity, and the most common valence are given in the following table for several elements; for those that are nonmetals, only atomic radii are indicated.

Element	**Atomic Radius (nm)**	**Crystal Structure**	**Electronegativity**	**Valence**
Ni	0.1246	FCC	1.8	+2
C	0.071			
H	0.046			
O	0.060			
Ag	0.1445	FCC	1.4	+1
Al	0.1431	FCC	1.5	+3
Co	0.1253	HCP	1.7	+2
Cr	0.1249	BCC	1.6	+3
Fe	0.1241	BCC	1.7	+2
Pt	0.1387	FCC	1.5	+2
Zn	0.1332	HCP	1.7	+2

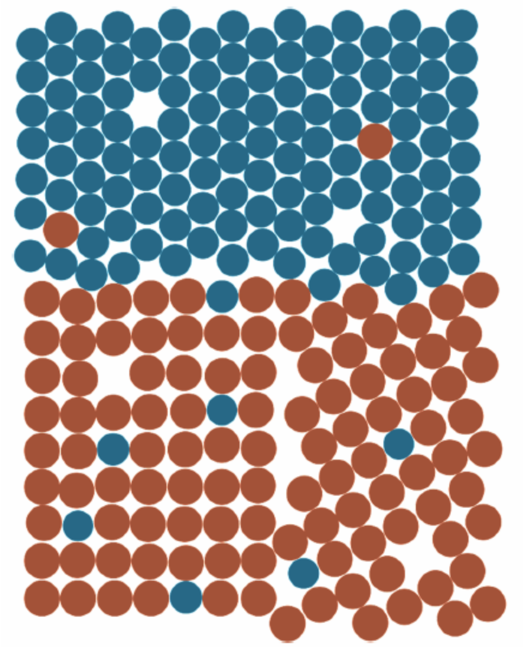
   Which of these elements would you expect to form the following with copper. Give a brief explanation of your choice.
   (a) A substitutional solid solution having complete solubility
   (b) A substitutional solid solution of incomplete solubility
   (c) An interstitial solid solution

5. What is the composition, in atom percent, of an alloy that consists of 60wt% Ni and 40% Ti?

6. Cite the relative Burgers vector–dislocation line orientations for edge, screw, and mixed dislocations.

7. For a BCC single crystal, would you expect the surface energy for a (100) plane to be greater or less than that for a (110) plane? Why? (hint: compare the planar density)

8. Consider the schematic nanostructure depicted below. Which of the following statements is FALSE regarding this schematic structure? Do not extrapolate the field of view. Consider only what you are shown. Give a brief explanation for your answer.



(a) Each of the phases features a similar concentration of vacancies.

(b) The microstructure features exactly two components and two different phases.

(c) None of the phases present features interstitial impurities.

(d) Only one phase boundary is depicted.

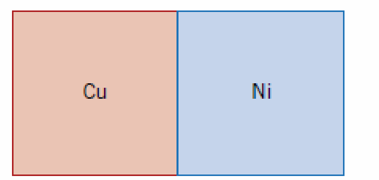
(e) Two grain boundaries are depicted.

9. The activation energy for the diffusion of carbon in chromium is 111,000 J/mol. Calculate the diffusion coefficient at 1100 K (827°C), given that D at 1400 K (1127°C) is 6.25×10^{-11} m^2/s.

10. For a low concentration of Ni in Fe (bcc α ferrite), the diffusion coefficient of Ni has been measured to be 2.2×10^{-15} m^2/s at 1200°C and 4.8×10^{-14} m^2/s at 1400°C. The gas constant is R = 8.31 J/mol-K.
    (a) What is the activation energy Q?
    (b) What is the constant D_o
    (c) What is the diffusion coefficient of Ni in Fe at 1300°C
    (d) For C in Fe (bcc α ferrite), $D_o = 1.1 \times 10^{-6}$ m^2/s and Q = 87.4 kJ/mol. Compute the diffusion coefficient of C in Fe at 1300°C.
    (e) Briefly describe the difference in diffusion coefficients (i.e. Ni in Fe vs. C in Fe) with respect to the underlying mechanisms of diffusion.

11. For a steel alloy it has been determined that a carburizing heat treatment of 10-h duration will raise the carbon concentration to 0.45 wt% at a point 2.5 mm from the surface. Estimate the time necessary to achieve the same concentration at a 5.0-mm position for an identical steel and at the same carburizing temperature.

12. A copper–nickel diffusion couple similar to that shown in the figure below. After a 700-h heat treatment at 1100°C (1373 K), the concentration of Cu is 2.5 wt% at the 3.0-mm position within the nickel. At what temperature must the diffusion couple need to be heated to produce this same concentration (i.e., 2.5 wt% Cu) at a 2.0-mm position after 700 h? The preexponential and activation energy for the diffusion of Cu in Ni are $2.7 \times 10^{-5}\ m^2/s$ and 256,000 J/mol, respectively.



13. Consider a diffusion couple composed of two semi-infinite solids of the same metal, and that each side of the diffusion couple has a different concentration of the same elemental impurity; furthermore, assume each impurity level is constant throughout its side of the diffusion couple. For this situation, the solution to Fick's second law (assuming that the diffusion coefficient for the impurity is independent of concentration), is as follows:

$$C_x = C_2 + \left(\frac{C_1 - C_2}{2}\right)\left[1 - \operatorname{erf}\left(\frac{x}{2\sqrt{Dt}}\right)\right]$$

The schematic diffusion profile the figure below shows these concentration parameters as well as concentration profiles at times t = 0 and t > 0. Please note that at t = 0, the x = 0 position is taken as the initial diffusion couple interface, whereas C_1 is the impurity concentration for x < 0, and C_2 is the impurity content for x > 0.

A diffusion couple composed of two silver-gold alloys is formed; these alloys have compositions of 98 wt% Ag–2 wt% Au and 95 wt% Ag–5 wt% Au. Determine the time this diffusion couple must be heated at 750ºC (1023 K) in order for the composition to be 2.5 wt% Au at the 50 mm position into the 2 wt% Au side of the diffusion couple. Preexponential and activation energy values for Au diffusion in Ag are 8.5×10^{-5} m^2/s and 202,100 J/mol, respectively.