ENGR 145 **Chemistry of Materials** **Fall 2023**

Exam #1
September 29, 2023
Duration: 55 minutes; 10:30 – 11:25 am EDT

Any resources (book, notes, web, etc.) are allowed, but you are not allowed to talk with anyone during the exam. With submission of your answers, you implicitly affirm that all work is your own, without consultation of peers or others. Be sure to cite sources of information.

Submit your answers via Canvas to your recitation instructor by 11:25 am EDT

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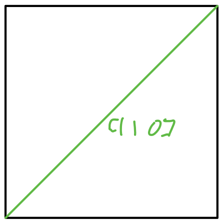
1a. Copper adopts the FCC cubic crystal structure. Calculate the linear density of atoms along the [110] direction in units of atoms/nm. The radius of a copper atom is 0.1278 nm. (13 points)

$$LD = \frac{\#\text{ atoms}}{\text{length}}$$



$$\text{length} = \sqrt{a^2+a^2} = \sqrt{2}a$$

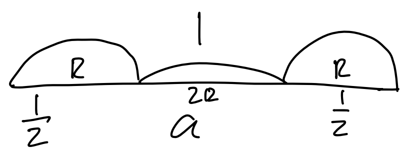
$$a = \frac{4R}{\sqrt{2}}$$

$$\text{length} = \sqrt{2}\left(\frac{4R}{\sqrt{2}}\right) = 4R$$

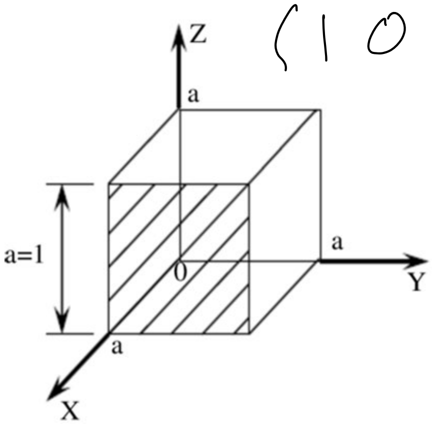
$$LD = \frac{2 \text{ atoms}}{4R}$$

$$LD = \frac{2}{4(.1278)} = 3.912 \text{ atoms/nm}$$

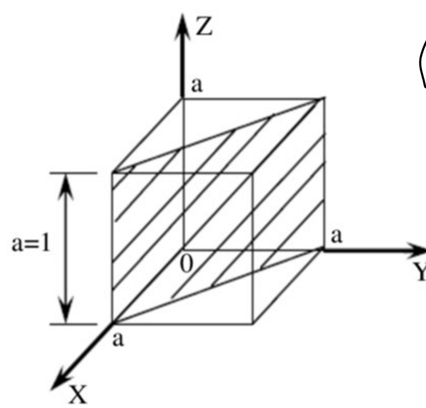
4Radii = 2atoms



b. Determine the Miller indices of the following planes: (12 points)



(1 0 0)



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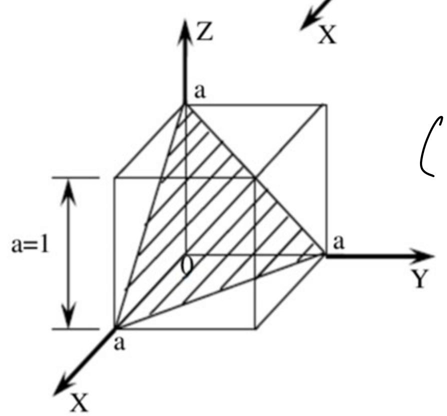
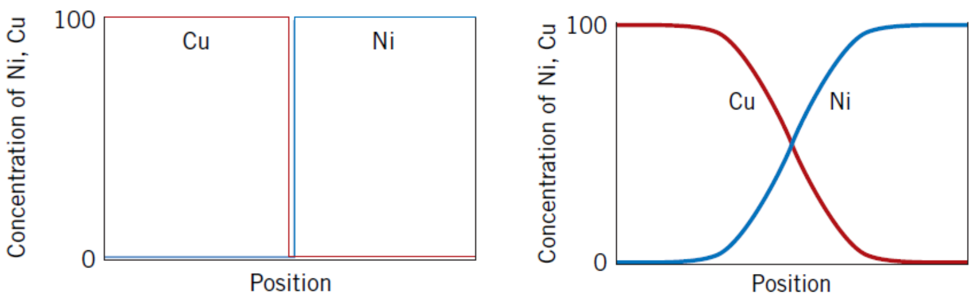


(1 1 1)

2. Consider an experiment where a thin bar of copper is pressed against a thin bar of nickel. The concentration profile is shown in (a) below. Next, the Cu-Ni sandwich is placed in an oven at an elevated temperature (less than the melting points of the two metals) for an extended period of time, and then cooled to room temperature. An analysis of the concentration profile after this sequence is shown in (b).



(a) (b)

a. Briefly explain the mechanism that allows the movement of Cu and Ni in opposite directions. (13 points)

This is because of vacancy diffusion. The temperature change allows vacancies to readily form, leading to Cu and Ni wanting to fill those vacancies. Because atoms move from high to low concentration, Cu and Ni move in opposite directions to fill the vacancies.

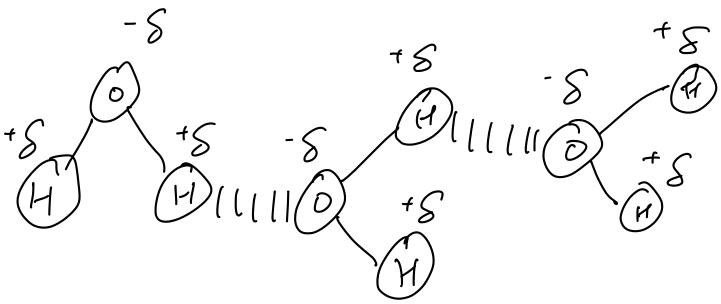
b. Why is the elevated temperature step needed to achieve migration of Cu and Ni? Explain with the aid of equations (hint: two) to strengthen your answer. (12 points)

Diffusion is a thermally activated process, so it needs a specific activation energy for diffusion to start. According to the eq. $N_v = N\exp\left(-\frac{Q_v}{RT}\right)$, the number of vacancies is exponentially related to Temperature. Temperature increases dramatically effect vacancies formation. A similar relationship can be found in the Diffusion Coeff. eq. $D = D_0\exp\left(-\frac{Q_d}{RT}\right)$, where the diffusion coeff. is exponentially related to Temperature.

3a. Briefly, outline the main differences between covalent and ionic bonding, and explain why covalent bonding is directional, whereas ionic bonding is not. (10 points)

Covalent bonding involves e^- sharing, while Ionic bonding occurs at high electronegativity differences, where e^- are transfered (opposite charge). Covalent bonds create a definite negative and positive side when the bond is formed making them directional. Ionic bonds attract in all directions, making them non-directional.

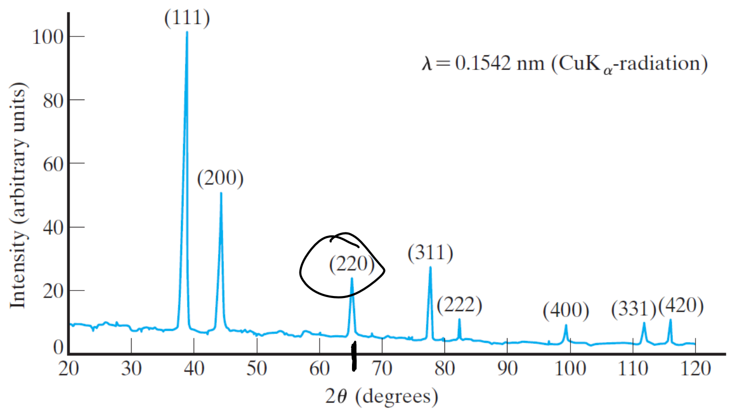
b. An important type of secondary bonding is referred to a hydrogen bond. It is especially important for water. Provide a sketch of at least three water molecules showing hydrogen bonding between them. (10 points)



c. Considering hydrogen bonding in water and with the aid of your sketch, explain briefly why ice is less dense than liquid water. (5 points)

In liquid water, the water molecules can move freely and make/break their H-bonds constantly. As ice is formed, these molecules form a crystal structure, which is much more rigid but takes up space. This increase in space usage correlates to a lower density of molecules.

4a. Shown below is an x-ray diffraction pattern for aluminum powder.



The lattice parameter, a, is 0.404 nm. Calculate the inter-planar spacing, d, of the (220) planes. (15 points)

$a = 0.404 \text{ nm}$ $\quad \theta = \frac{66^\circ}{2} = 33^\circ$

$n\lambda = 2d\sin\theta$

$$d = \frac{a_0}{\sqrt{h^2+k^2+\ell^2}} = \frac{0.404 \text{ nm}}{\sqrt{2^2+2^2+0^2}}$$

$$= \frac{0.404 \text{ nm}}{\sqrt{8}} = 0.1428 \text{ nm}$$

Alternate method

$$d = \frac{n\lambda}{2\sin\theta}$$

$$d = \frac{1(.1542 \text{ nm})}{2\sin 33}$$

$$= 0.1416 \text{ nm}$$

b. Draw the (220) and (311) planes in the cube below. Label the three axes properly. (10 points)