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

Sample Exam #1

September, 2023

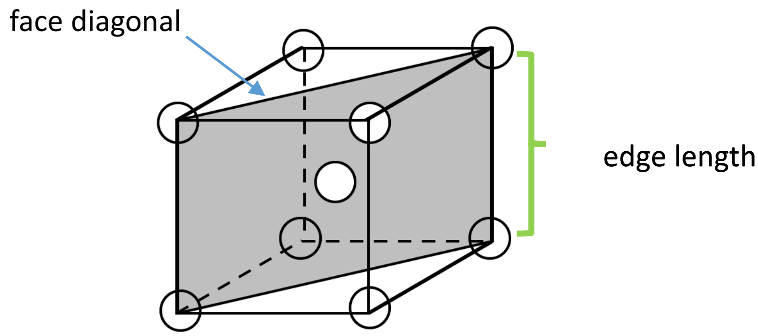
Duration: 55 minutes; 10:30 – 11:25 am EDT

Open resources (book, notes, web, etc.), but you are not allowed to talk with anyone during the exam

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

1a. Calculate the planar density of atoms in the (110) plane of bcc vanadium per square meter. The radius of a vanadium atom is 0.134 nm. (15 points)

The BCC unit cell with the (110) plane is



Within the (110) plane of a BCC crystal, there are 2 atoms (4 x ¼ from the corners, and 1 in the center). Since 2 full atoms touch along the body diagonal (1 in the center, and 2 x ½ at the edges), the body diagonal (BD) is 4r the unit cell edge length, or a, is 4r/√3. We now need to obtain an equation for a face diagonal (FD). From the Pythagorean Theorem, $(BD)^2 = (FD)^2 + a^2$. Solving for the FD:

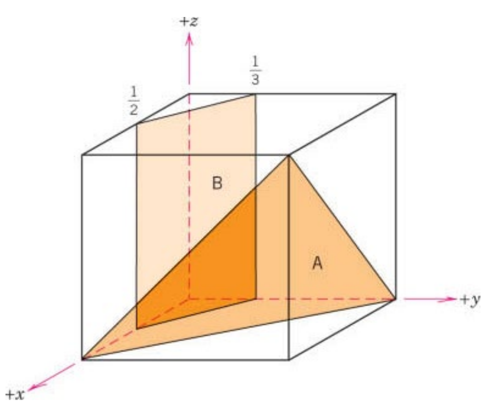
$$FD = 4r\sqrt{2}/\sqrt{3}$$

$$Area\ (110) = 4r\sqrt{3} \times 4r\sqrt{2}/\sqrt{3} = ,16\ r^2.,-\sqrt{2}/3$$

Planar Density (110) = 2 atoms/ area = $3/8r^2\sqrt{2}$

Given r_V = 0.134 nm, PD = $1.524 \times 10^{19}/m^2$

b. Determine the Miller indices of the planes shown in the unit cell below. (10 points)



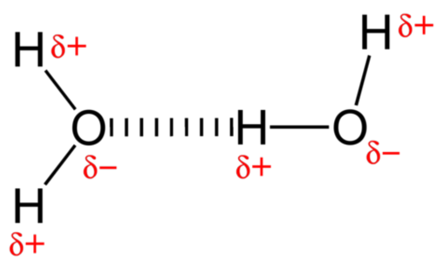
Plane A: The x and y axes are intersected at x = +1 and y = +1; however, z will be intersected at z = -1. Hence the plane is $(11\bar{1})$.

Plane B: Take reciprocals at the intercepts ½, 1/3, and infinity. Thus the plane is (230).

2a. Briefly, cite the main differences among ionic, covalent, and metallic bonding. (10 points)

Covalent bonding: sharing of electrons; ionic bonding: attraction between ions of opposite charge; metallic bonding: delocalized sharing of easily-ionized valence electrons.

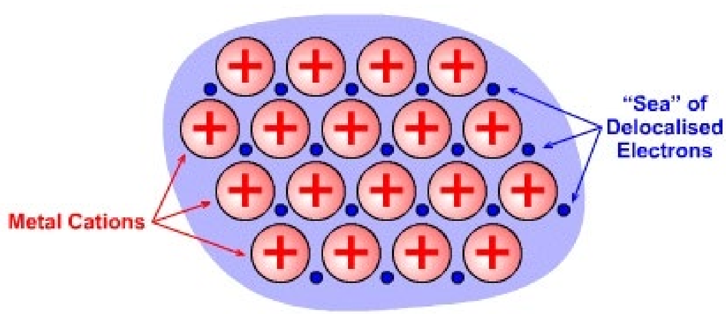
b. An important type of secondary bonding is hydrogen bonding. Illustrate a hydrogen bond using water as an example. (10 points)
For example:



https://courses.lumenlearning.com/cheminter/chapter/hydrogen-bonding

c. Sketch your interpretation of the 'sea-of-electrons' model for a metal, and use it to explain the good electrical conductivities of metals. (5 points)

Something like



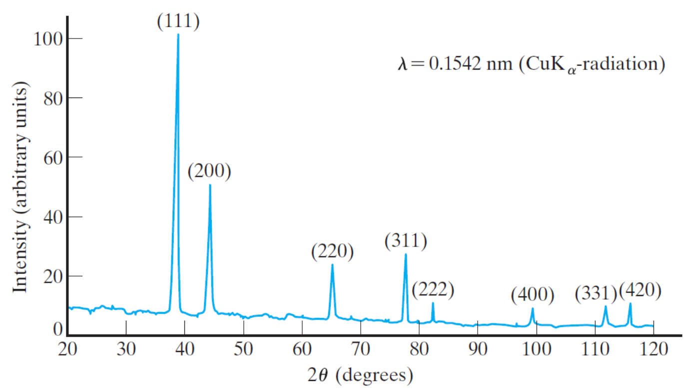
https://mattsgcsenotes.wordpress.com/2016/12/27/1-46-understand-that-a-metal-can-be-described-as-a-giant-structure-of-positive-ions-surrounded-by-a-sea-of-delocalised-electrons

Briefly, the delocalized electrons (the 'sea') are loosely bound to nuclei and are thus free to 'roam.' Such electrons can move easily in the presence of an electrical potential difference.

3a. In your own words, explain briefly why x-rays, as opposed to say microwaves, are able to show diffraction from metallic crystals such as FCC copper. (10 points)

Diffraction requires a periodic structure, as in a crystal, in order to achieve constructive reinforcement of electromagnetic radiation and the observation of sharp diffraction lines. The wavelength of the electromagnetic radiation for diffraction must be comparable to inter-planar spacing in crystals which are in the ca. 0.1-0.3 nm range. Thus, x-rays are ideal for diffraction from crystals. The wavelength of microwaves is much too long.

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



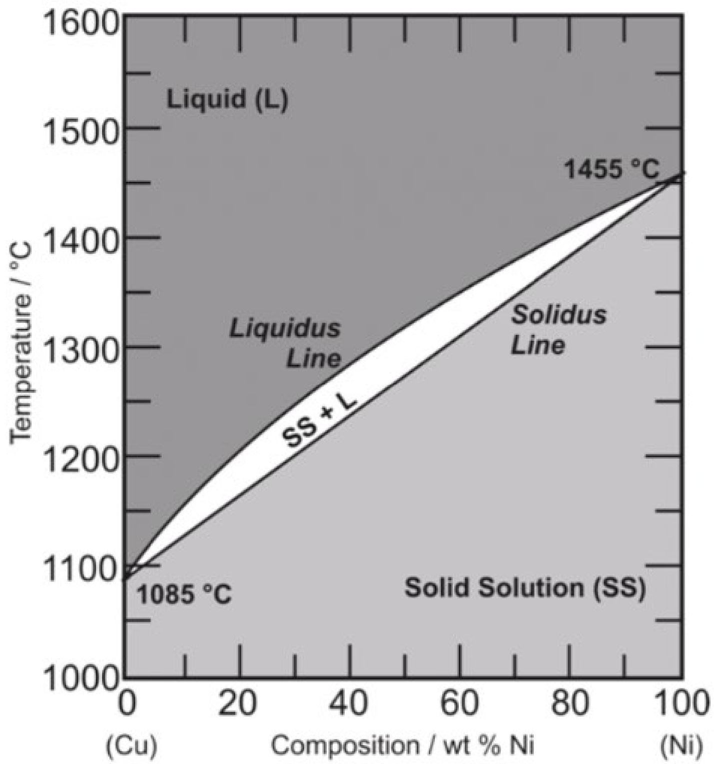
The lattice parameter, a, is 0.404 nm. Calculate the inter-planar spacing, d, of the (111) planes. (15 points)

$$d_{hkl} = \frac{a_0}{\sqrt{h^2 + k^2 + l^2}}$$

$\mathbf{d_{111} = 0.404/\sqrt{3}}$

$\mathbf{d_{111} = 0.234\ nm}$

4. The Cu-Ni phase diagram below.



a. Consider a sample, say 1 kg, with 50 wt% Ni. How many phases, and which ones, are present at 1400^{o}C, 1280^{o}C, and 1100^{o}C? (13 points)

1400^{o}C: molten liquid only

1280^{o}C: molten liquid and solid solution

1200^{o}C: solid solution only

b. For each temperature, calculate the weight fraction of each phase present. (12 points)

1400^{o}C: 100 w% L

1280^{o}C: draw a tie line across the SS+L section. By eyeball, it appears that 50wt% Ni sits in the middle of the line. Therefore, using the lever rule, there will be 50 wt% L and 50 wt% SS. Thus, the weight fraction of each is 50wt% L and 50 wt% SS.

1200^{o}C: 100 wt% SS