ENGR/MSE 170 B Midterm 4/30/01 100pts. Total

Exam is closed book, closed notes, closed neighbors

(one sheet of letter-size paper is allowed)

Instruction:

1. *Write your name and student ID on top of page.*
2. *Write legibly.*
3. *Show work as needed to justify answers*
4. *Circle all final numerical answers*

Problem 1 (15 points): Bonding and interatomic forces

a. Referring to the periodic Table on page 8, determine what are predominant bondings for SiC, BaS and aluminum phosphide (AlP)?

Sic : Covalent

Bas : Ionic

AlP : Ionic + Covalent

b. Briefly describe the main differences between ionic, covalent and metallic bonding.

Ionic: Metallic atoms gives up $\bar{e}$ to non-metalic ones, Nondirectional bond.

Covalent: Atoms share $\bar{e}$, Directional bond

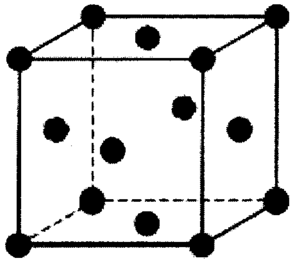
Metallic: "electron cloud" around "ion cores" as valence $\bar{e}$, Non directional bond.

c. Explain why hydrogen fluoride (HF) has a higher boiling temperature than hydrogen chloride (HCl) (19.4 v.s. -850 C), even though HF has a lower molecular weight.

The intermolecular bonding for HF is hydrogen bond while for Hcl is Van der Waals. Since the hydrogen bond is stronger than vander Waals, HF has a higher Tm.

Problem 2 (15 points) Crystal structures

a. Draw a face centered cubic unit cell.

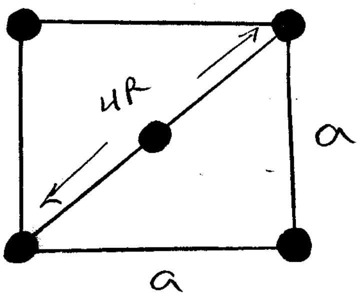


b. Determine the number of atoms per unit cell for the face centered cubic (FCC) structure.

$$N_o = \frac{1}{8} \times 8 + 6 \times \frac{1}{2} = 4$$

c. What is the relationship between the atomic radius and the lattice parameter (i.e. the edge length of the unit cell) for the FCC structure.

$$(4R)^2 = a^2 + a^2 \Rightarrow 16R^2 = 2a^2 \Rightarrow a = 2\sqrt{2}R$$



d. Given the information below, calculate the theoretical density of aluminum (which has an FCC structure): Atomic weight =26.96 g/mol; atomic radius $=0.143 \times 10^{-9}$ m; Avagadro's number=6.023×10^{23} atoms/mol.

$$\rho = \frac{nA}{V_C N_A}$$

$$V_C = a^3 = (2\sqrt{2}R)^3 = (2\sqrt{2} \times 0.143\times10^{-9})^3$$

$$= 6.62\times10^{-29}\ m^3/\text{unit cell}$$

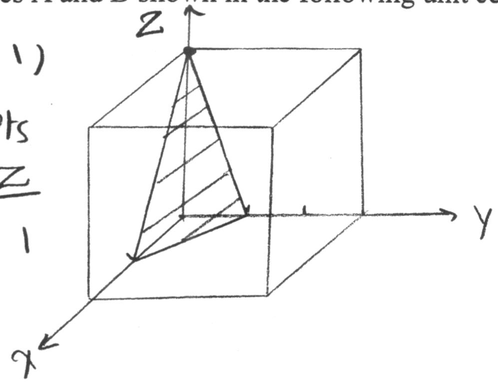
$$\rho = \frac{(4\ \text{atoms/unit cell})(26.96\ g/mol)}{(6.62\times10^{-29}\ m^3/\text{unit cell})(6.023\times10^{23}\ \text{atoms/mol})}$$

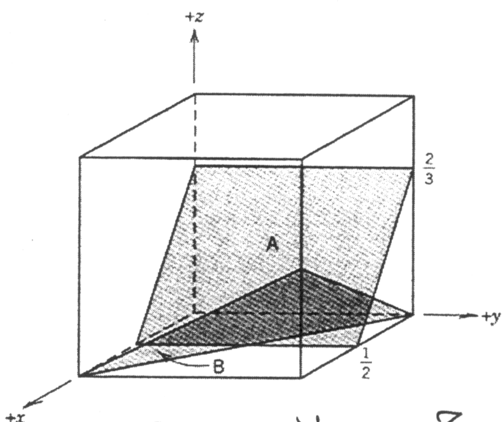
$$= 2.71\times10^{6}\ g/m^3 = 2.71\ g/cm^3$$

e. Sketch crystallographic plane (231) in a cubic unit cell and determine the Miller indices for the planes A and B shown in the following unit cell.

plane (231) has intercepts of:

x	y	z
$\frac{1}{2}$	$\frac{1}{3}$	1





A:

	x	y	z
intercepts:	$\frac{a}{2}$	∞b	$\frac{2c}{3}$
intercepts in terms of a, b, c:	$\frac{1}{2}$	∞	$\frac{2}{3}$
reciprocals:	2	0	$\frac{3}{2}$
Reduction:	4	0	3

$\Rightarrow$ A: (403)

B:

	x	y	z
intercepts:	$-a$	$-b$	$\frac{c}{2}$
intercepts in terms of a,b,c:	-1	-1	$\frac{1}{2}$
reciprocals:	-1	-1	2

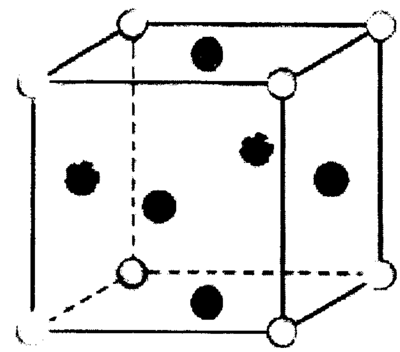
B: $(\bar{1}\bar{1}2)$

Problem 3 (15 points): Defects

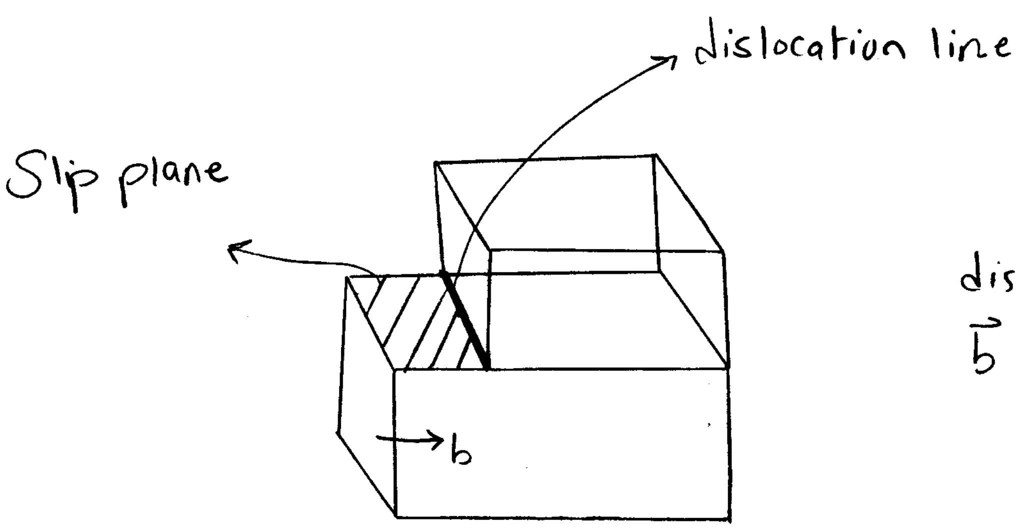
a. List at least 3 types of defects appeared in solids. If interstitial atoms occupy 6 face-centered voids (circles in shade) in a unit cell shown in the following figure, determine the numbers of interstitials per the unit cell.

Point, Line, Interface.

No of interstitials per unit cell : $6 \times \frac{1}{2} = 3$



b. Draw a 3-D edge dislocation. Label the dislocation line and slip plane. Indicate the relation between the dislocation line and Burger's vector.



dislocation $\perp \vec{b}$

$\vec{b}$ is Burger's vector

Problem 4 (15 points) Diffusion

a. Assuming steady-state conditions, calculate the flux (including the correct units) of carbon atoms diffusing through a 5 mm thick stainless steel. The concentration of carbon on the low and high pressure sides are 0.4 kg/m^3 and 4 kg/m^3, respectively. Assuming this occurs at 500^{0}C and a diffusion coefficient of $3\text{x}10^{-11}$m^2/s.

$$J = -D \frac{\Delta C}{\Delta x} = -3\times10^{-11}\ m^2/s \cdot \frac{(0.4-4)\ kg/m^3}{5\times10^{-3}\ m}$$

$$= 2.16\times10^{-8}\ kg/m^2 \cdot s$$

b. Would the flux be higher or lower at 600°C? Why?

The flux would increase since $D = D_0 \exp\left(-\frac{Q}{RT}\right)$

D increases with T

The flux increases with D

c. Determine what diffusion mechanism dominates the process?

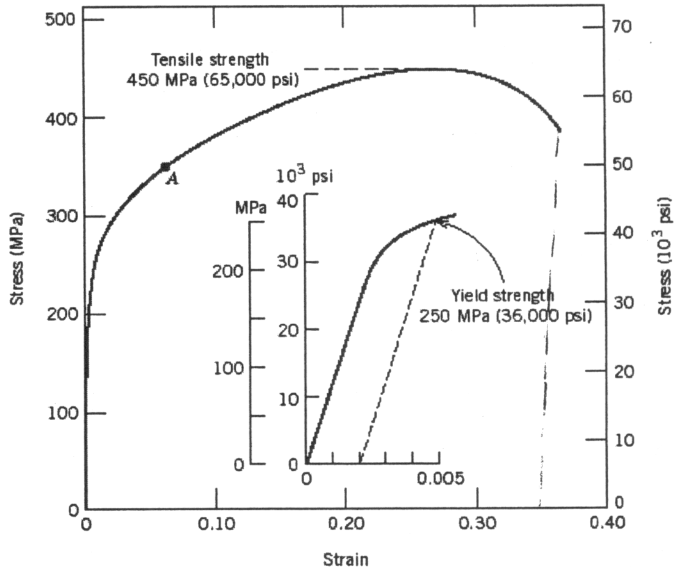
Interstitial

Problem 5 (20 points). Mechanical properties & plastic deformation

From the stress-strain plot for brass (a Cu-Zn alloy) shown in the figure below, answer the following questions:

a. What is the ductility of the brass alloy?

~ 35%



b. If a rod made from this brass alloy has a cross-sectional area of 0.04 in^2 and 12 in long, calculate the magnitude of the force needed to produce a total elongation of 0.06 in(while under the load):

$A_o = 0.04 \text{ in}^2 \qquad l_o = 12 \text{ in}$

$\varepsilon = \frac{\Delta l}{l_o} = \frac{0.06 \text{ in}}{12 \text{ in}} = 0.005$

For this total strain, stress must be $\sim 37 \times 10^3$ psi

$\sigma = \frac{F}{A_o} \Rightarrow F = \sigma A_o = (37 \times 10^3 \text{ psi})(0.04 \text{ in}^2)$

$= 1480$ lbs

c. What would be the net elongation after the load is removed?

Follows elastic unloading line

$\varepsilon_{permanent} = 0.002$

$\Delta l = l_o . \varepsilon_{permanent} = 0.002 \times 12 = 0.0024$

Problem 6 (20 points). Plastic deformation

a. List types of hardness tests. Which is only for microhardness testing?

Brinell, vickers, Knoop and Rockwell tests.

Vickers and Knoop are for microhardness testing.

b. What is the main mechanism to cause the plastic deformation of metals?

Dislocation movement.

c. List three mechanisms for strengthening metals. Briefly explain why these would strengthen metals?

1) Grain Size reduction: Grain boundry acts as a barrier to dislocation motion and smaller size grains have more grain boundries than large ones.

2) Solid Solution: Impurity atoms impose lattice strains on the surrounding host atoms, and strain field interactions impede dislocation movement.

3) Strain hardening: Dislocation - dislocation interactions impede dislocation movement.