ANSWER KEY

MSE 170 A Midterm 10/27/2008 100pts. Total
Exam is closed book, closed notes, no collaborations with neighbors.

(One sheet of letter-size paper is allowed)

Instructions:

1. *Write your name and student ID on the top of the page.*
2. *Read the questions carefully.*
3. *Read the questions carefully, again.*
4. *Make sure you are answering the right questions.*
5. *Write legibly.*
6. *Show work as needed to justify answers.*
7. *After you are done, hand in your work and as once a wise man said: " Do a little dance, ..."*

Point Break Down (total=100)

Problem 1	*15*
Problem 2	*25*
Problem 3	*10*
Problem 4	*10*
Problem 5	*25*
Problem 6	*15*

Problem 1 (15 points): Bonding and interatomic forces

a. Referring to the periodic Table on page 11, determine what is the predominant type of bonds for CsCl (Cesium Chloride), BN (Boron Nitride), and solid Co. Why? (6)

CsCl Ionic (1) – big difference in electronegativity (1) or – far away on the peridic table

BN Covalent (1) Small difference in electronegativity (1) or close by on the periodic table

Co metallic (1) metallic bonding is found for all elemental metals (1)

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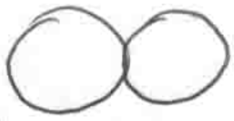
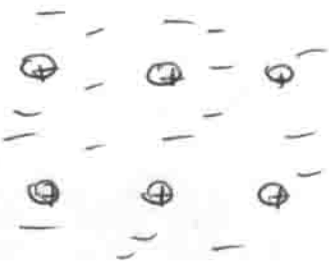
b. Briefly describe the main differences between ionic, covalent, and metallic bonding (draw sketches and a few words)(5).

(1) 

Ionic

(1) 

Covalent

(1) 

Charge

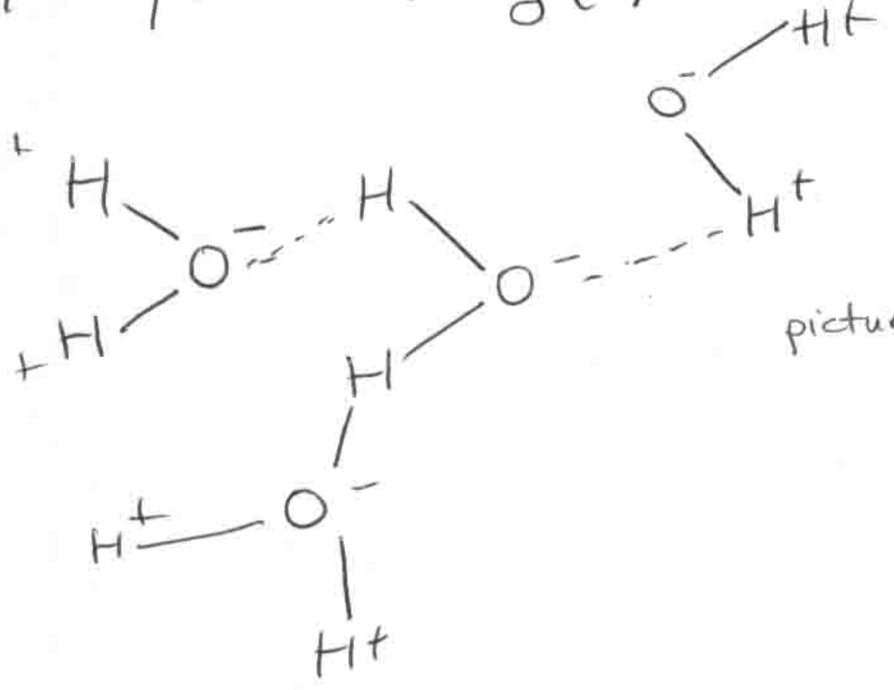
Share electrons

sea of electrons
electron cloud

2 points for overall good explanations + sketches

c. Explain why H_2O is liquid at room temperature (draw a cartoon of the molecules)(4).

H_2O is liquid at RT because of hydrogen bonding (2)



picture (2)

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Problem 2 (25 points): Crystal structures

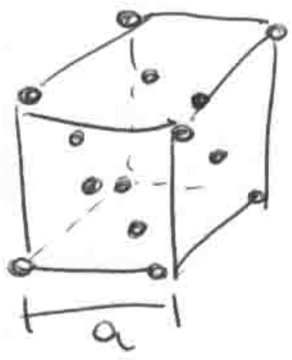
a. What is a unit cell? (2)

repeat unit of a crystal lattice

or

small repeat ~~entit~~ entity

b. Draw a unit cell for an FCC structure(3).



b. Determine the atomic packing factor for a FCC structure (make sure you draw the appropriate sketches and explain your answers) (10)

$$APF = \frac{\text{Volume atoms}}{\text{Unit cell volume}} \quad (1)$$

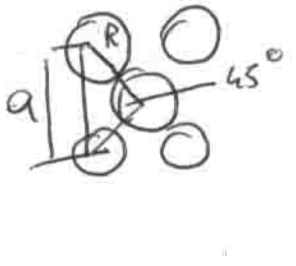
number of atoms in FCC 4 (1)

explain (1)

Volume sphere $\frac{4}{3}\pi R^3$

Volume unit cell a^3 (1)

$a = 2R\sqrt{2}$ (2)



(1)

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$$APF = \frac{4 \cdot \frac{4}{3}\pi R^3}{8 \cdot 2 \cdot \sqrt{2}\, R^3} =$$ (2)

$$= \frac{\pi}{3\sqrt{2}} = 0.74$$ (2)

c. Draw a Sodium Chloride structure, and determine the type of unit cell and the coordination number for both cation and anion (5).

(2) drawing

unit cell (1)
Rock salt
or
two interpenetrating FCC

C# 6 (1)
Same cation and ion (1)

5/5

d. Determine the Miller indices for the planes in the unit cell shown in Figure 1(5).

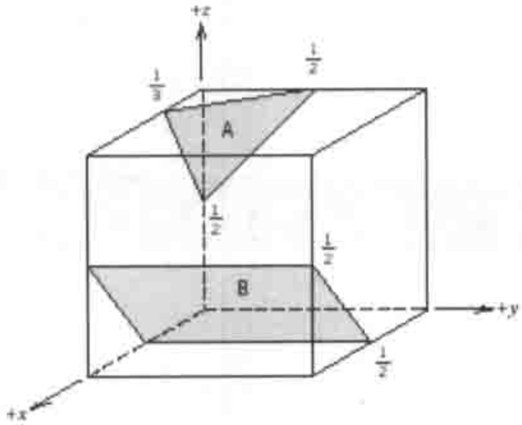

Figure 1

A. intersections

$\frac{1}{3}$ $\frac{1}{2}$ $-\frac{1}{2}$

reciprocal (1)

3 2 -2

reduction (1)

3 2 -2

$(3\ 2\ \bar{2})$ $(\frac{1}{2})$

also accept: $(3 2 \bar{2})$ $(\bar{2} \bar{3} 2)$
$(\bar{3} \bar{2} 2)$ $(\bar{2} 2 \bar{3})$

B. intersections

$\frac{1}{2}$ ∞ $-\frac{1}{2}$ OR $-\frac{1}{2}$ ∞ $\frac{1}{2}$

reciprocals

2 0 -2 -2 0 2 (1)

reduction (1)

1 0 -1 -1 0 1

$(1\ 0\ \bar{1})$ $(\bar{1}\ 0\ 1)$ $(\frac{1}{2})$

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Problem 3 (10 points): Defects

a. List at least 3 types of defects that are present in solids. Which defect plays a major role in influencing plastic deformation of materials? (4)

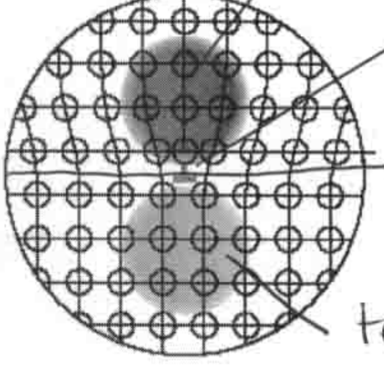
* impurities — interstitials or substitutional atoms
* vacancies
* dislocations
* grain boundaries

1 point per type

* point
* linear
* planar

dislocations play major role (1)

b. Indicate the type the dislocation below, and label the dislocation line and slip plane. Indicate the type of stress above and below the slip plane. (6)



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Problem 4 (10 points) Diffusion

a. Given Fick's first law of diffusion $J = -D\frac{dC}{dx}$ define all the quantities present in the equation and state which assumption was made to derive it (6).

J = flux (1)

D = diffusion coefficient (1)

$\frac{dC}{dx}$ = concentration gradient (2)

OR

C = concentration (1)

x = space and gradient, distance (1)

Assumption: steady state OR time independent (2)

b. Qualitatively describe the dependence of D on temperature and explain how this dependence relates to Q_d (diffusion activation energy) (4).

T ↑ , D ↑ (2)

$D \sim e^{-Q_d/RT}$ (2)

OR

Q_d is the activation energy for diffusion

RT is the thermal energy of a mole of substance at temperature T

diffusion is thermally activated

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Problem 5 (25 points) Mechanical Properties

From the stress-strain plot for brass (a Cu-Zn alloy) shown in the Figure 2:

a. Estimate the modulus of elasticity and yield strength (put labels on graph)(8).

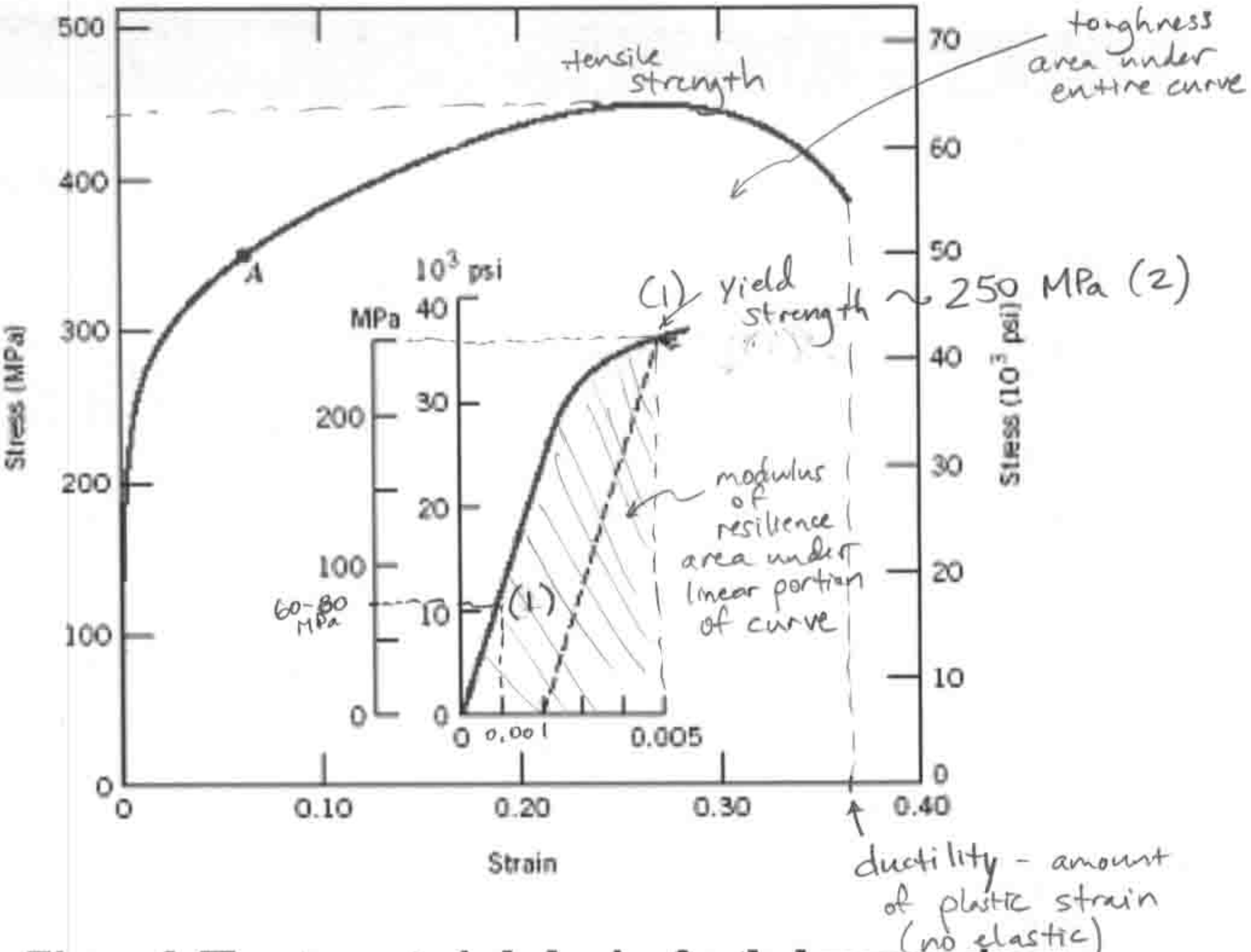

Figure 2. The stress-strain behavior for the brass specimen

Modulus of Elasticity

$\sigma = E\varepsilon \qquad E = \frac{\sigma}{\varepsilon}$ (2)

$E = \frac{60-80 \text{ MPa}}{0.001} \approx 60-80 \text{ GPa}$ (2)

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b. Estimate the strain when a tensile load 100 MPa is applied on a cylindrical specimen. Is it elastic, plastic or both (explain)(5)?

Strain ~ 0.0014 ± 0.0002 (2)

no plastic — elastic (2)

below yield strength (1)

c. Label tensile strength, resilience, toughness, and ductility on the figure and briefly explain their physical meaning (12).

Labels
tensile strength (1)
resilience (1)
toughness (1)
ductility (1)

Explanation

t.s. → maximum stress on plot (2)

resilience → amount of energy that a material can store elastically (2)

toughness → total energy absorbed before break (2)
plastic

ductility → percentage of elongation or plastic strain at fracture (2)

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Problem 6 (15 points). Plastic deformation and fracture

a. Complete the following sentence (2):

Virtually all strengthening techniques rely on this simple principle: reduce

dislocation motion (or similar)

b. List three strategies to reduce dislocation motion and explain their mechanisms (draw sketches)(9)

- grain size reduction (1) → dislocations do not move at boundaries (2)
- solid solution strengthening (1) → Strain induce by impurities blocks dislocation (2)
- Strain hardening (1) → increase dislocation density (2)

c. List the types of fracture modes (draw sketches for a sample exposed to a tensile stress) (2) For safety reasons, is one type more desirable than the other(s) (2)? / why

ductile (1)
brittle (1)

ok if they also list moderately ductile

ductile because is more predictable (2)
and/or more energy is required

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