I. EXAMINATION

(Answer any three of the four questions)

1. a. Define nominal stress, true stress, strain, Young's modulus and linear thermal expansion coefficient.

   b. A steel bar 1.0 in. in diameter is subjected to a load of 60,000 lbs. What is the stress placed on the bar? If the modulus of elasticity of steel is 30×10^6 psi, what is the strain on this bar?

   This bar was observed to break under a load of 100,000 lbs; its final diameter was 0.75 in. Calculate its true breaking strength. Will this be greater or smaller than the nominal breaking strength?

2.(a) Distinguish between substitutional and interstitial solid solutions. Indicate the type of solid solution formed by the following pairs of elements: (i) Fe and C (ii) Fe and Ni (iii) Cu and Zn (iv) Fe and N (v) Cu and Ni.

(b) Compare and contrast the volume changes occurring in crystals and glasses upon cooling.

(c) State Fick's first law for diffusion. The coefficient of diffusion (D) of zinc in copper can be found from the following data: Do = 0.34 cm^2/sec., Q = 45,600~~0~~ cals/mole. How much should the concentration gradient be for Zinc in copper if a flux of 10^7 zinc atoms/cm^2 sec. is to be obtained at a temperature of 727°C? The gas constant, R = 1.9872 cals/mole °K.

*3. a. Define coordination number. How does it vary with the ratio of ion sizes (= r/R; r = smaller ion radius, R = larger ion radius)?

   b. What is the radius of the smallest cation that can have a six-fold coordination with Cl^- without distortion? (R_{Cl^-} = 1.81 Å)

   c. Distinguish between simple cubic, body-centered cubic and face-centered cubic unit cells. How many atoms are there per unit cell in each case?

   d. Gold is face-centered cubic. Its lattice parameter is 4.076 Å and its atomic weight is 197.0. Show that its density is 19.3 gms./cm^3.

*4. a. Define atomic packing factor and planar density.

   b. What is the value of $[111] \times [\bar{1}\bar{1}\bar{1}]$ in a cubic crystal?

   c. Sketch the following directions and planes in a BCC unit cell: [100], [211], (100) and (123).

   d. X-rays with a wavelength of 0.58 Å are used for calculating d_{200} in nickel. The reflection angle θ is 9.5°. What is the size (a) of the unit cell?

*NOTE: In questions 3 and 4, you need to answer only three of the four parts.

1.b. $\sigma = \frac{6\times10^4}{(\pi/4)\,1^2} = 76394$ psi (526.7 MPa)

$\varepsilon = \sigma/E = \frac{76394}{30\times10^6} = \underline{0.00255}$

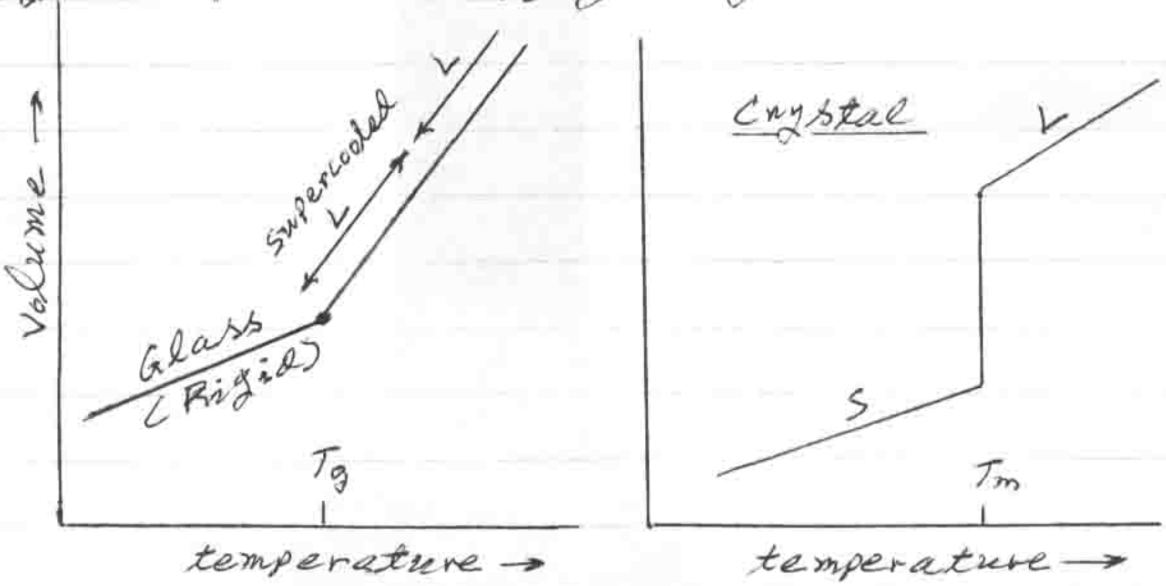
$\sigma_{tr} = \frac{100000}{(\pi/4)(0.75)^2} = \underline{226354 \text{ psi}}$ (1560.7 MPa)

Nominal breaking strength:

$\sigma = 100000/(\pi/4) = \underline{127324 \text{ psi}}$ (877.9 MPa)

2a. Fe-C, Fe-N : interstitial; rest : substitutional

2b. Crystal shows sharp change (at T_m) in volume. In glasses, volume change is gradual.



T_g : glass transition temp. T_m : melting point

2c. $D = 0.34\exp\left(-\frac{45600}{R\,1000}\right) = 0.368\times10^{-10}\ \text{cm}^2/\text{s}$

Fick's 1st law:

$J_{Zn} = -D\cdot\frac{\Delta C}{\Delta x} = 10^7\ \text{atoms/cm}^2\cdot\text{s}$

$\frac{\Delta C}{\Delta x} = -2.719\times10^{17}\ \frac{\text{atoms}}{\text{cm}^4}$

$= \underline{-4.515\times10^{-7}\ \frac{\text{mole}}{\text{cm}^4}}$

3b. cation radius : $r = 0.41(1.81) = 0.75\,\text{Å} = \underline{0.075\text{-nm}}$

upper limit for CN = 6 : $r = 1.325\,\text{Å} = 0.1325\text{-nm}$

3c. atoms/unit cell : 1 2 4

crystal : Simple cubic BCC FCC

3d. Four atoms per unit cell :

$$\text{mass} = 4 \frac{197}{6.022 \times 10^{23}} \text{ g}$$

$$\text{Volume} = a^3$$

$$\text{density} = \frac{4 \times 197}{6.022 \times 10^{23} \times (4.076 \times 10^{-8})^3} = \underline{19.3 \frac{g}{cm^3}}$$

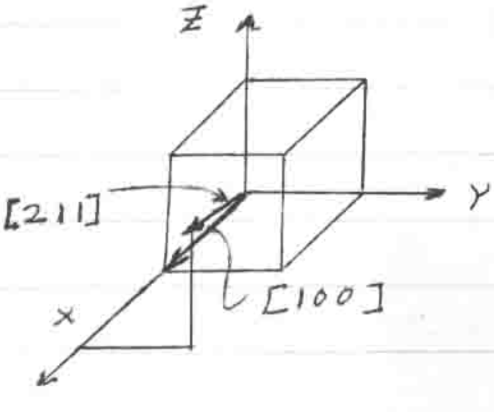
4b. $\mathbf{A} \cdot \mathbf{B} = AB \cos\theta = a_1 b_1 + a_2 b_2 + a_3 b_3$

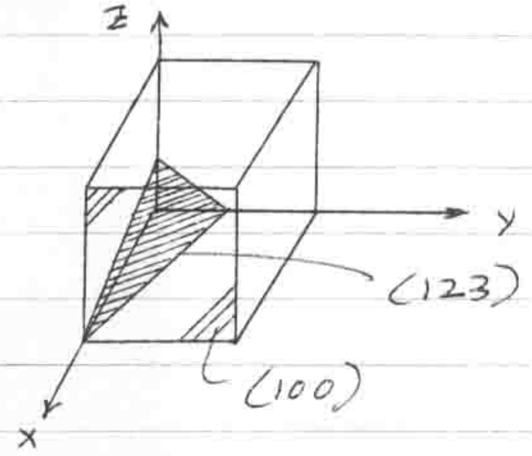
$$A = (a_1^2 + a_2^2 + a_3^2)^{1/2} = \sqrt{3}$$

$$B = (b_1^2 + b_2^2 + b_3^2)^{1/2} = \sqrt{3}$$

$$\cos\theta = -3/(\sqrt{3} \cdot \sqrt{3}) = -1 \ ; \ \underline{\theta = 180^\circ}$$

4c.





4d. Bragg's law :

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

$$0.58 = 2 d_{200} \sin 9.5$$

$$d_{200} = 1.757\,\text{Å} = \frac{a}{(2^2 + 0 + 0)^{1/2}} = \frac{a}{2}$$

$$a = 3.514\,\text{Å}$$

$\underline{(0.3514\text{-nm})}$