Fall 2018 Test 1

Monday, October 8, 2018   6:44 PM

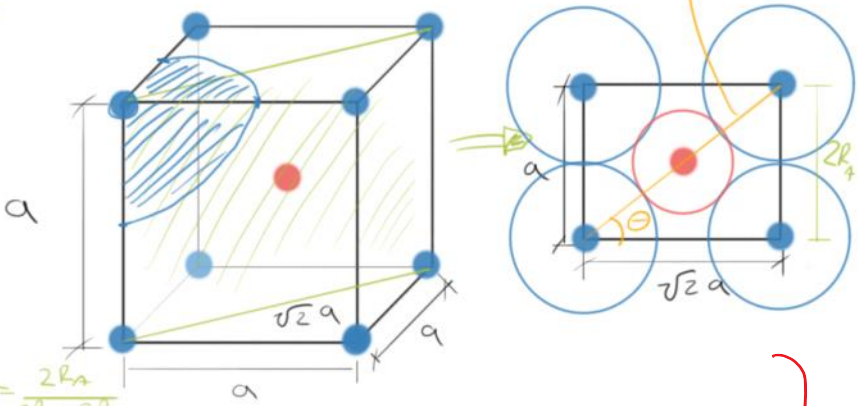
Part B.

1. Show that the ratio of cation radius to anion radius for a coordination number of 8 is 0.732. (10)

MCQ	
1	B
2	B, D
3	D
4	C
5	C
6	D
7	D
8	D
9	D
10	A

geometry (3)

contact relationship (3)



$$\sin\theta = \frac{2R_A}{2R_A + 2R_C}$$

$$\frac{R_A \sin\theta}{R_A} + \frac{R_C \sin\theta}{R_A} = \frac{R_A}{R_A} \Rightarrow \frac{R_C}{R_A} = \frac{1-\sin\theta}{\sin\theta}$$

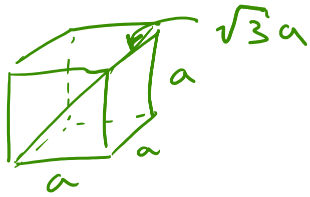
work (4)

$$\theta = \tan^{-1}\left(\frac{1}{\sqrt{2}}\right) = 35.3^\circ$$

$$\frac{R_C}{R_A} = 0.732$$

, simple cubic

or cube diagonal $= 2R_A + 2R_C$



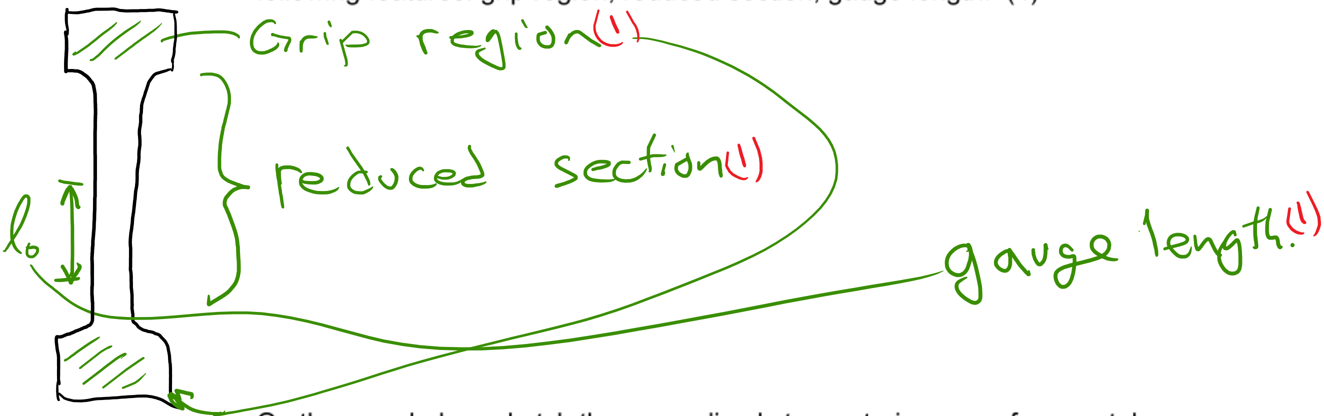
so $2R_A + 2R_C = \sqrt{3}\,a$

but $a = 2R_A$, so $2R_A + 2R_C = 2R_A \cdot \sqrt{3}$

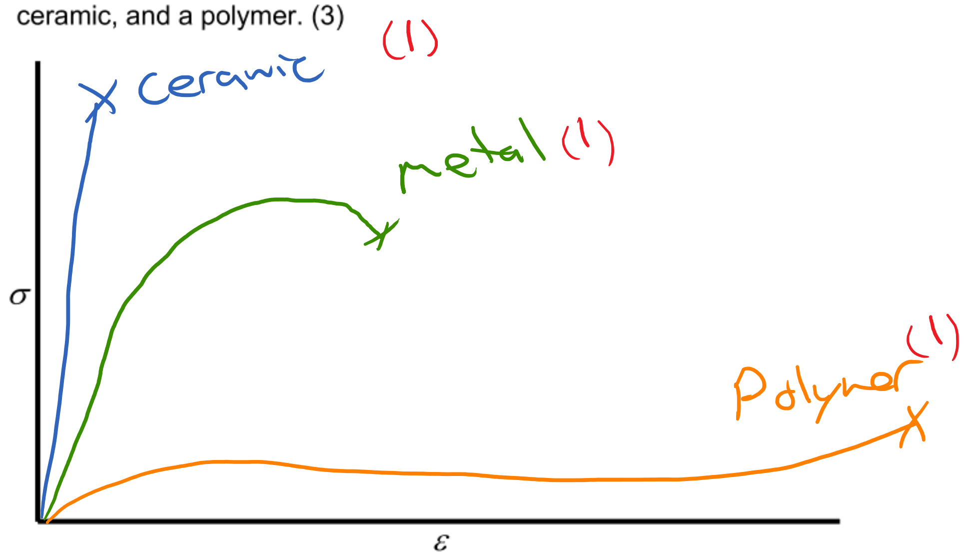
$$1 + \frac{R_C}{R_A} = \sqrt{3} \Rightarrow \frac{R_C}{R_A} = \sqrt{3} - 1 = 0.732$$

Sketch (1)

2. This question pertains to the tensile test.
   a. Draw a typical metallic tensile specimen. On your sketch, identify the following features: grip region, reduced section, gauge length. (4)



   b. On the axes below, sketch the generalized stress strain curves for a metal, ceramic, and a polymer. (3)



   c. Explain why, in the characterization of materials, engineering stress and engineering strain are used rather than force and elongation. (1)

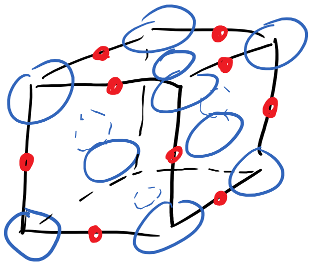
σ & ε are sample size independent! (1)

   d. Provide two differences between elastic and plastic deformation. (2)

Elastic (1)
- atoms do not move to new positions
- sample returns to original dimensions (1)

Plastic
- atoms move to new positions.
- sample does not return to original dimensions.

3. Strontium selenide (SrSe) forms the rock salt crystal structure and has a density of $4.54\ \frac{g}{cm^3}$. The radius of the selenium anion in this structure is 184 pm. Calculate the radius of the strontium cation in this structure, in pm. Note: 1 pm = 10^{-12} m. (10)



$a = 2R_A + 2R_C$

$$\underbrace{\rho = \frac{n_C A_C + n_A A_A}{V_C \cdot N_A}}_{(1)}$$

$\left.\begin{array}{l} n_A = 4 \\ n_C = 4 \end{array}\right\} (1)$

$A_A = 78.96\ g/mol$

$A_C = 87.62\ g/mol$

$\rho = 4.54(10^6)\ g/m^3$

$V_C = a^3$

$\underbrace{a = 2R_A + 2R_C}_{(3)}$

$$\rho = \frac{n_C A_C + n_A A_A}{(2R_A + 2R_C)^3 N_A}$$

work (3)

$$2R_A + 2R_C = \left(\frac{n_C A_C + n_A A_A}{\rho N_A}\right)^{1/3}$$

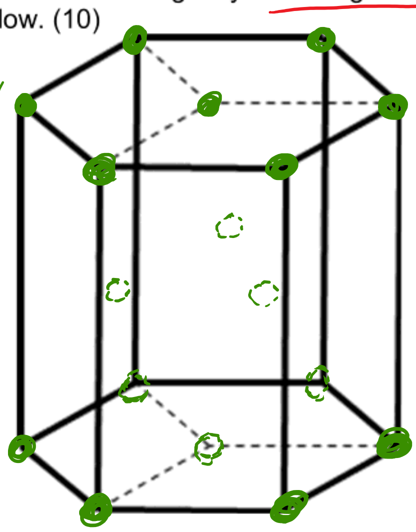
$$R_C = \frac{\left(\frac{n_C A_C + n_A A_A}{\rho N_A}\right)^{1/3} - 2R_A}{2}$$

$$= \frac{\left(\frac{4(87.62) + 4(78.96)}{4.54(10^6) \cdot 6.022(10^{23})}\right)^{1/3} - 2(184(10^{-12}))}{2}$$

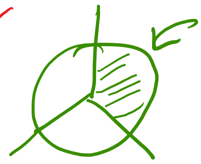
$$= 1.28(10^{-10})\ m = \underbrace{128}_{(1)}\ \underbrace{pm}_{(1)}$$

this knowledge (3)

4. The volume of an HCP unit cell is $\frac{3\sqrt{3}}{2}a^2c$. Show that the atomic packing factor of the HCP crystal structure is 0.74. Begin by sketching the atom positions, as small dots, in the unit cell below. (10)



Since APF = 0.74.



1/6 at each vertex

1/2 each face

3 internal

and $a = 2R$.

or $R = a/2$

atom positions (3)

so $12 \cdot \frac{1}{6} + 2 \cdot \frac{1}{2} + 3 = 6$ atoms.

$$0.74 = \frac{6 \cdot \frac{4}{3}\pi R^3}{\frac{3\sqrt{3}}{2}(2R)^2 \cdot c} \Rightarrow c = \frac{2 \cdot 6 \cdot \cancel{4} \cdot \pi \, a}{2 \cdot \cancel{3} \cdot 3 \cdot \sqrt{3} \cdot \cancel{4} \cdot 0.74}$$

$$\frac{c}{a} = \frac{2\pi}{3\sqrt{3} \cdot 0.74} = 1.63$$

okay if memorized this.

$$\Rightarrow c = 1.63 \cdot a = 1.63 \cdot (2R)$$

$$\text{So, } APF = \frac{6 \cdot \frac{4}{3}\pi R^3}{\frac{3\sqrt{3}}{2}(2R)^2 \cdot 1.63(2R)} = \frac{6 \cdot \cancel{4} \cdot \pi \cdot \cancel{2}}{3\sqrt{3} \cdot \cancel{4} \cdot \cancel{2} \cdot 1.63}$$

$$= \frac{2\pi}{3\sqrt{3} \cdot 1.63} = \underline{0.74}$$

work (4)

or (1) knowing $a = 2R$

(1) for $c = 3.26R$