PHYS 321 Test #2 S2022 Name: KEY

Braggs's Law	Inter-planar Spacing	Hydrogen Like Spectra (R= 1.097 x 10^7 m^{-1})
$2d_{hkl}Sin\theta = n\lambda$	$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$	$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f{}^2} - \frac{1}{n_i{}^2}\right)$

1. The voltage across an X-ray tube is 47.0 kV. The tungsten ($Z = 74$) is the target in the X-ray tube. Determine **(a)** the tube's cutoff wavelength **(b)** the wavelength of the K_α *and* L_β - ray lines emitted by the tungsten target.

(a) $E = \frac{hc}{\lambda} = eV$

$\lambda = \frac{hc}{eV}$

$\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times47\times10^{3}}$

$\lambda = 0.264\times10^{-10}$ m $= 0.0264$ nm

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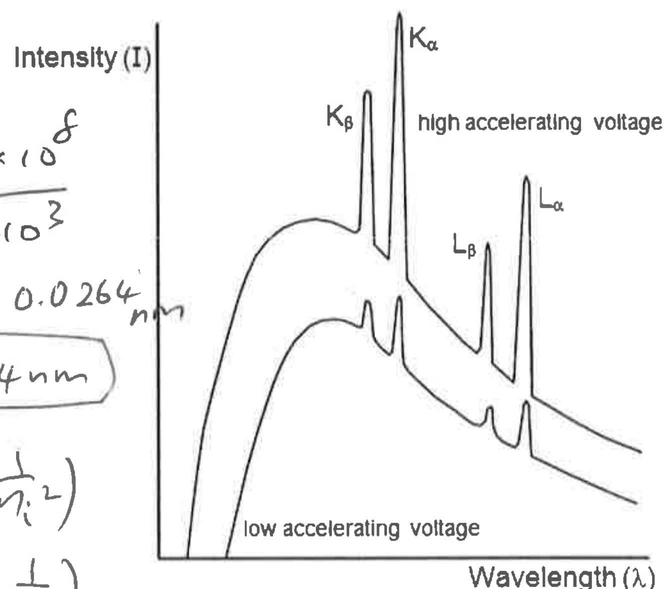


(b) $\frac{1}{\lambda_{K\alpha}} = R(Z-1)^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$= R(74-1)^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$\frac{1}{\lambda_{K\alpha}} = 1.097\times10^7\times73^2\times\left(1-\frac{1}{4}\right) = 4384.4\times10^7$

$\lambda_{K\alpha} = \frac{1}{4384.4\times10^7} = 2.280\times10^{-4}\times10^{-7}$ m

$= 2.28\times10^{-11}$ m $= 0.0228$ nm

$\frac{1}{\lambda_{L\beta}} = R(Z-7.4)^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$= 1.097\times10^7\times(74-7.4)^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 912.3\times10^7$

$\lambda_{L\beta} = \frac{1}{912.3\times10^7} = 0.001096\times10^{-7}$ m

$\lambda_{L\beta} = 0.1096$ nm

Bragg's law for X-ray diffraction:

$$2d_{hkl} Sin\theta = n\lambda \qquad d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}.$$

Additional Conditions: BCC: $h+k+l$=even FCC: h,k,l either odd or even

2. The 2Θ values in degrees for diffraction peaks are given below for a metal with cubic structure, using X-rays of wavelength 0.1542 nm: 37.21, 43.23, 62.86, 75.31, 79.32.

(a) Derive an expression for

$$\frac{Sin^2\theta}{h^2+k^2+l^2}$$

$$2\frac{a}{\sqrt{h^2+k^2+l^2}} \cdot Sin\theta = \lambda$$

$$\frac{sin^2\theta}{h^2+k^2+l^2} = \frac{\lambda^2}{4a^2}$$

(b) Complete the table below.

(c) Determine the crystal structure. (FCC)

(d) Determine the lattice constant.

(e) Determine the ionic radius.

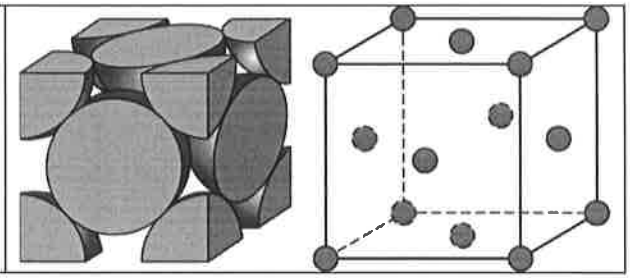
2θ (deg.)	θ	Sin²θ	Normalize	Clear Fractions	h²+k²+l²	(hkl)	$\frac{Sin^2\theta}{h^2+k^2+l^2}$
37.21	18.605	0.102	1	3	3	(111)	0.034
43.23	21.615	0.134	1.31	4	4	(200)	0.034
62.86	31.43	0.272	2.67	8	8	(220)	0.034
75.31	37.655	0.373	3.66	11	11	(311)	0.034
79.32	39.66	0.407	3.99	12	12	(222)	0.034

FCC

$$\frac{\lambda^2}{4a^2} = 0.034$$

$a = 0.418\ nm \rightarrow \sqrt{2}a = 4R$

$R = 0.148\ nm$

$\rho_{ave} = \dfrac{100}{\dfrac{C_1}{\rho_1} + \dfrac{C_2}{\rho_2}}$	$A_{ave} = \dfrac{100}{\dfrac{C_1}{A_1} + \dfrac{C_2}{A_2}}$	

3. Silver and palladium both have the FCC crystal structure, and Pd forms a substitutional solid solution for all concentrations at room temperature. Compute the unit cell edge length for a 65 wt% Ag–35 wt% Pd alloy. The room-temperature density of Pd is 12.02 g/cm^3, and its atomic weight is 106.4 g/mol. The room-temperature density of Ag is 10.49 g/cm^3, and its atomic weight is 107.9 g/mol.

$$\rho_{ave} = \frac{100}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}} = \frac{100}{\frac{65}{10.49} + \frac{35}{12.02}} = 10.98 \frac{g}{cm^3}$$

$$A_{ave} = \frac{100}{\frac{C_1}{A_1} + \frac{C_2}{A_2}} = \frac{100}{\frac{65}{107.9} + \frac{35}{106.4}} = 107.4 \frac{g}{mol}$$

$$\rho = \frac{m}{V} \qquad V = \frac{m}{\rho} = \frac{4 \cdot A_{ave}/N_A}{10.98}$$

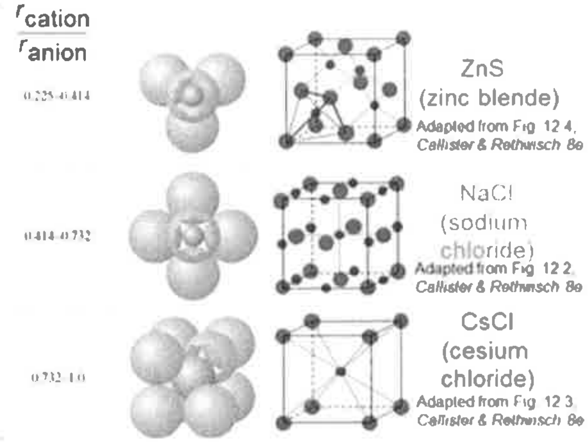
$$a^3 = \frac{4 \cdot 107.4}{10.98 \times 6.022 \times 10^{23}}$$

$$a = \left[\frac{4 \times 107.4}{10.98 \times 6.022 \times 10^{23}}\right]^{1/3} = 4.02 \times 10^{-8} cm$$

$$\boxed{a = 0.402 nm}$$

Table 12.3 Ionic Radii for Several Cations and Anions (for a Coordination Number of 6)

Cation	*Ionic Radius (nm)*	*Anion*	*Ionic Radius (nm)*
Al^{3+}	0.053	Br^-	0.196
Ba^{2+}	0.136	Cl^-	0.181
Ca^{2+}	0.100	F^-	0.133
Cs^+	0.170	I^-	0.220
Fe^{2+}	0.077	O^{2-}	0.140
Fe^{3+}	0.069	S^{2-}	0.184
K^+	0.138		
Mg^{2+}	0.072		
Mn^{2+}	0.067		
Na^+	0.102		
Ni^{2+}	0.069		
Si^{4+}	0.040		
Ti^{4+}	0.061		



4. On the basis of ionic charge and ionic radii given in Table 12.3, predict crystal structures for the following materials:

(a) CsI

(b) NiO

(c) KI

(d) NiS

Justify your selections.

(a) CsI $\frac{r_{Cs^+}}{r_{I^-}} = \frac{0.170}{0.220} = 0.773$ → CsCl structure

(b) NiO $\frac{r_{Ni^{2+}}}{r_{O^{2-}}} = \frac{0.069}{0.140} = 0.493$ → NaCl structure

(c) KI $\frac{r_{K^+}}{r_{I^-}} = \frac{0.138}{0.220} = 0.627$ → NaCl structure

(d) NiS $\frac{r_{Ni^{2+}}}{r_{S^{2-}}} = \frac{0.069}{0.184} = 0.375$ → Zinc blende Str

$R = \frac{\rho l}{A}$ the resistivity of aluminum is 2.7×10^{-8} Ω-m **V = IR J = I/A E = V/L**

5. (a) Compute the resistance of an aluminum wire 5 mm (0.20 in.) in diameter and 5 m (200 in.) in length.

$$R = \frac{\rho l}{A} = \frac{2.7\times10^{-8}\times 5}{\pi\times(2.5\times10^{-3})^2} = 6.89\times10^{-3}\ \Omega$$

(b) What would be the current flow if the potential drop across the ends of the wire is 0.04 V?

$$I = V/R = \frac{0.04}{6.89\times10^{-3}} = 5.81\ A$$

(c) What is the current density?

$$J = I/A = \frac{5.81}{\pi\times(2.5\times10^{-3})^2} = 2.96\times10^{5}\ A/m^2$$

(d) What is the magnitude of the electric field across the ends of the wire?

$$E = V/L = \frac{0.04}{5m} = 0.008\ V/m$$

$$\sigma = n|e|\mu_e + p|e|\mu_h$$

6. The following electrical characteristics have been determined for both intrinsic and p-type extrinsic indium phosphide (InP) at room temperature:

	σ (Ω -m)$^{-1}$	n (m^{-3})	p (m^{-3})
Intrinsic	2.5×10^{-6}	3.0×10^{13}	3.0×10^{13}
Extrinsic (n-type)	3.6×10^{-5}	4.5×10^{14}	2.0×10^{12}

Calculate electron and hole mobilities. $\sigma = ne\mu_e + pe\mu_h$

$$3.6\times10^{-5} = 4.5\times10^{14}\times1.6\times10^{-19}\times\mu_e + 2\times10^{12}\times1.6\times10^{-19}\mu_h$$

$$112.4 = 225\mu_e + \mu_h \quad (1)$$

$$2.5\times10^{-6} = 3\times10^{13}\times1.6\times10^{-19}\mu_e + 3\times10^{13}\times1.6\times10^{-19}\mu_h$$

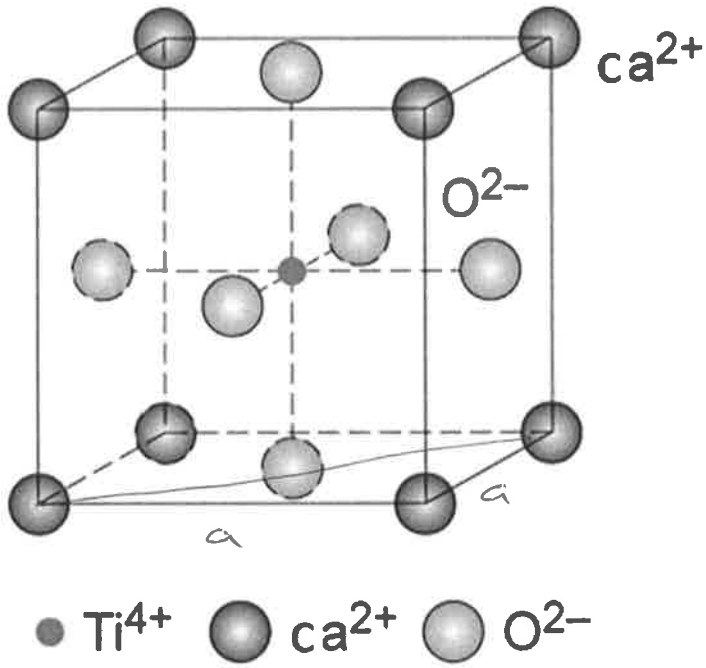
$$0.52 = \mu_e + \mu_h \quad (2)$$

(1) − (2)

$$112.4 - 0.52 = 224\mu_e \rightarrow \mu_e = 0.5\ m^2/V.s$$

$$\mu_h = 0.02\ m^2/V.s$$

7. Calculate the Density of $CaTiO_3$.



	Ti^{4+}	Ca^{2+}	O^{2-}
Radius	0.145 nm	0.100 nm	0.140 nm
Atomic weight	47.88 g	40.08 g	16 g

$$\sqrt{2}\,a = 2R_{Ca} + 2R_O$$

$$\sqrt{2}\,a = 2 \times 0.100 + 2 \times 0.140$$

$$a = \frac{2 \times 0.100 + 2 \times 0.140}{\sqrt{2}} = 0.339\,nm$$

$$\rho = \frac{m}{V} = \frac{3A_O + 1A_{Ti} + 1A_{Ca}}{N_A \times (0.339 \times 10^{-7})^3} = \frac{3 \times 16 + 47.88 + 40.08}{6.022 \times 10^{23} \times (0.339 \times 10^{-7})^3}$$

$$\boxed{\rho = 5.8\ g/cm^3}$$