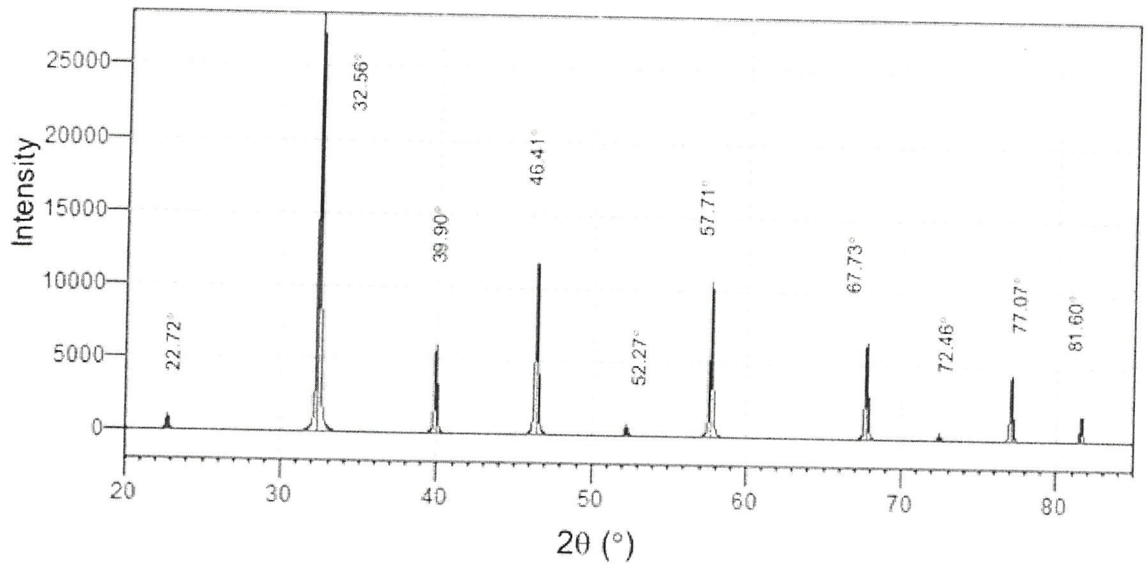
PHYS 321 S 2025 Test #2 Name: Answer Key

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 2Θ values in degrees for first order diffraction peaks are given above for strontium titanate, with cubic structure, using X-rays of wavelength 0.154 nm.

(a) Enter the above diffraction angles in the data table below and complete the rest of the columns.

2θ (deg.)	θ (deg.)	$Sin^2\theta$	Normalize	Clear Fractions	$h^2+k^2+l^2$	(hkl)	$\frac{Sin^2\theta}{h^2+k^2+l^2}$
22.72	11.36	0.0388	1	1	1	(100)	0.0388
32.56	16.28	0.0786	2.0255	2	2	(110)	0.0388
39.90	19.95	0.1164	3.00	3	3	(111)	0.0388
46.41	23.205	0.1553	4.00	4	4	(200)	0.0388
52.27	26.135	0.194	5.00	5	5	(210)	0.0388
57.71	28.855	0.2329	6.00	6	6	(211)	0.0388
67.73	33.865	0.3105	8.00	8	8	(220)	0.0388
72.46	36.23	0.3493	9.00	9	9	(221)	0.0388
77.07	38.535	0.3881	10.00	10	10	(310)	0.0388
81.60	40.8	0.427	11.00	11	11	(311)	0.0388

(b) Derive an expression for $\frac{Sin^2\theta}{h^2+k^2+l^2}$.

$2d_{hkl}\sin\theta = n\lambda = \lambda$

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

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

(c) Determine the lattice constant.

from Table (a) $\frac{\sin^2\theta}{h^2+k^2+l^2} = 0.0388 = \frac{\lambda^2}{4a^2}$

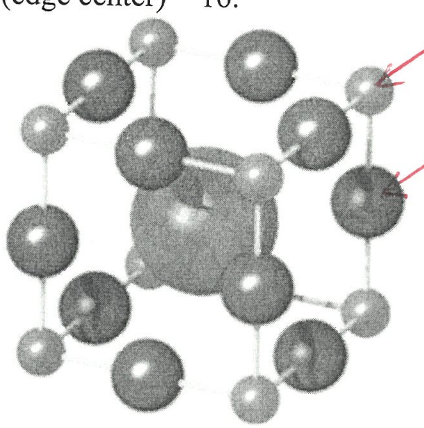
$\lambda = 0.154\,nm \longrightarrow 4a^2 = \frac{\lambda^2}{0.0388} = \frac{0.154^2}{0.0388}$

$a^2 = \frac{0.154^2}{0.0388}\times\frac{1}{4} = 0.1528$

$a = \sqrt{0.1528} = 0.3909\,nm$

$\boxed{a = 0.3909\,nm}$

(d) Calculate the lattice constant using the crystal structure shown below and the density of 5.1 g/cm^3, for strontium titanate. Atomic masses: Sr (body center) = 87.62, Ti (corner) = 47.87, O (edge center) = 16.



$Ti = \frac{1}{8}\times 8 = 1$

$O = \frac{1}{4}\times 12 = 3$

$\rho = \frac{m}{V}$

$V = \frac{m}{\rho} = \frac{87.62 + 47.87 + 3\times 16}{6.022\times 10^{23}\times 5.1}$

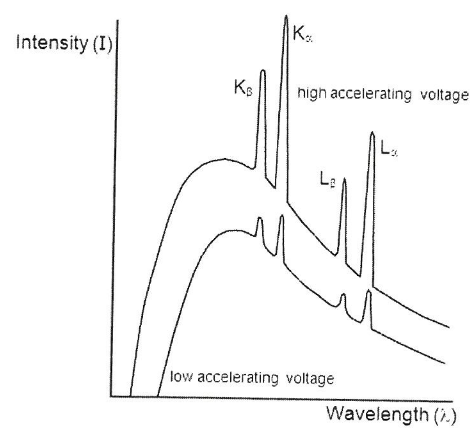
$V = 5.98\times 10^{-23}\,cm^3$

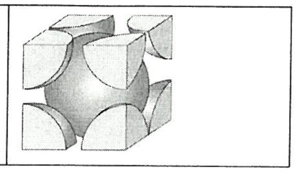
$a = (V)^{1/3} = 3.91\times 10^{-8}\,cm$

$\boxed{a = 0.391\,nm}$

2. Write down the n_i and n_f energy level values for each of the line spectra.

	n_i	n_f
K_α	2	1
K_β	3	1
L_α	3	2
L_β	4	2



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

3. Calculate the unit cell edge length for an 64.8 wt% V-35.2 wt% Nb alloy. All of the niobium is in solid solution, and, at room temperature the crystal structure for this alloy is BCC. The room-temperature density of Nb is 8.57 g/cm^3, and its atomic weight is 92.91 g/mol. The room-temperature density of V is 6.10 g/cm^3, and its atomic weight is 50.94 g/mol.

$$\rho_{ave} = \frac{100}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}} = \frac{100}{\frac{64.8}{6.10} + \frac{35.2}{8.57}} = 6.79\ g/cm^3$$

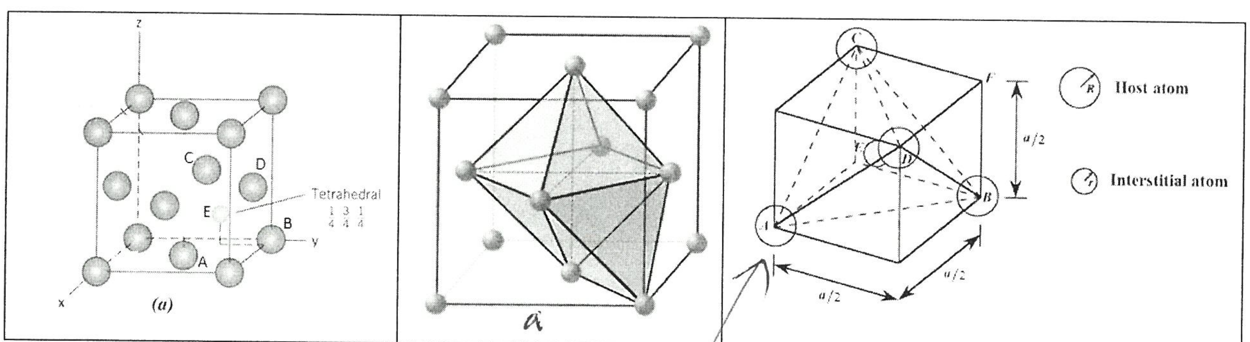
$$A_{ave} = \frac{100}{\frac{C_1}{A_1} + \frac{C_2}{A_2}} = \frac{100}{\frac{64.8}{50.94} + \frac{35.2}{92.91}} = 60.57\ g/mol$$

$$\rho = \frac{m}{V} \rightarrow V = \frac{m}{\rho} = \frac{2 \times 60.57}{6.022 \times 10^{23} \times 6.79} = 2.96 \times 10^{-23}\ cm^3$$

$$a = V^{1/3} = (2.96 \times 10^{-23})^{1/3} = 3.09 \times 10^{-8}\ cm$$

$$\boxed{a = 0.309\ nm}$$

4. Compute the radius r of an impurity atom that will just fit into an FCC tetrahedral site in terms of the atomic radius R of the host atom (without introducing lattice strains).



$$\sqrt{2}a = 4R$$
$$a = \frac{4R}{\sqrt{2}}$$
$$\frac{a}{2} = \frac{2R}{\sqrt{2}}$$

$$AEF^2 = AB^2 + BF^2$$
$$(2R+2r)^2 = \left(\frac{a}{2}\cdot\sqrt{2}\right)^2 + \left(\frac{a}{2}\right)^2$$
$$(2R+2r)^2 = \left(\frac{2R}{\sqrt{2}}\cdot\sqrt{2}\right)^2 + \left(\frac{2R}{\sqrt{2}}\right)^2$$
$$[2(R+r)]^2 = (2R)^2 + (\sqrt{2}R)^2 = 4R^2 + 2R^2$$
$$[2(R+r)]^2 = 6R^2$$
$$2(R+r) = \sqrt{6}\cdot R$$
$$R + r = \frac{\sqrt{6}}{2}\cdot R \longrightarrow r = \frac{\sqrt{6}}{2}R - R$$
$$r = \left(\frac{\sqrt{6}}{2} - 1\right)R = 0.225$$
$$\boxed{r = 0.225R}$$

5. $R = \frac{\rho l}{A}$ conductivity of copper is 6.0×10^{7} $(\Omega\text{-m})^{-1}$ **V = IR** **J = I/A** **E = V/L**

(a) Compute the resistance of a copper wire 3 mm (0.12 in.) in diameter and 2 m (78.7 in.) long.
(b) What would be the current flow if the potential drop across the ends of the wire is 0.05 V?
(c) What is the current density? (d) What is the magnitude of the electric field across the ends of the wire?

(a) $R = \frac{\rho l}{A} = \frac{l}{\sigma A}$

$R = \frac{2}{6\times10^{7}\times\pi\times(1.5\times10^{-3})^2}$

$R = 0.00472\,\Omega$

(b) $I = \frac{V}{R} = \frac{0.05}{0.00472} = 10.6\,A$

(c) $J = \frac{I}{A} = \frac{10.6}{\pi(1.5\times10^{-3})^2} = 1.5\times10^{6}\ A/m^2$

(d) $E = \frac{V}{L} = \frac{0.05}{2} = 0.025\ V/m$

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

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

	$\sigma\ (\Omega\text{-}m)^{-1}$	$n\ (m^{-3})$	$p\ (m^{-3})$
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.

$\sigma = ne\mu_e + pe\mu_h$

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

$0.5208 = \mu_e + \mu_h$ — (1)

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

Negligible

$$\boxed{\begin{aligned}\mu_e &= 0.5\ \frac{m^2}{V.s}\\ \mu_h &= 0.021\ \frac{m^2}{V.s}\end{aligned}}$$