Problem #1 (20%)

(a) In your search for a highly accurate measurement of the value of the wavelength of the copper K_α line you consult the U.S. Geological Survey website and discover the following:

$\lambda\,(K_\alpha) = 1.541838$ Å $\quad \lambda\,(K_{\alpha_1}) = 1.540562$ Å $\quad \lambda\,(K_{\alpha_2}) = 1.544390$ Å

What is the origin of the K_{α_1} and K_{α_2} lines?

(8%)

K_{α_1} : $2p \rightarrow 1s$

K_{α_2} : $2s \rightarrow 1s$

(b) You suspect that the silver you purchased on eBay is contaminated with a heavy metal. The x-ray emission spectrum of your metal reveals the presence of a K_α line at $\lambda = 1.80 \times 10^{-11}$ m. What is the impurity?

(12%)

use Moseley's Law

$$\bar{\nu} = \frac{1}{\lambda} = \frac{3}{4} R (Z-1)^2$$

$$\therefore \frac{4}{3} \cdot \frac{1}{\lambda R} = (Z-1)^2$$

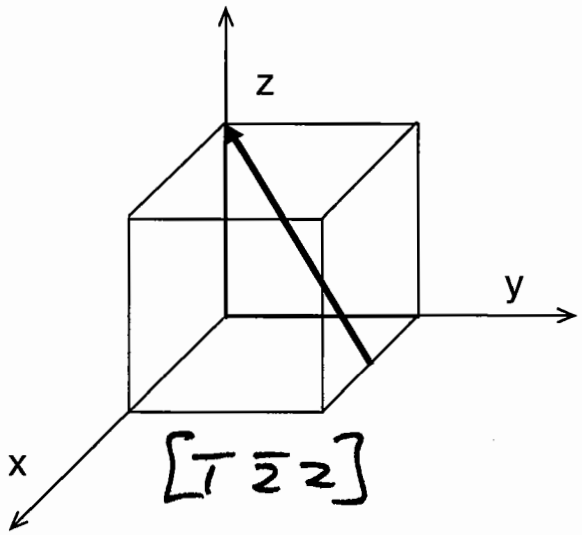
$$\therefore Z - 1 = \frac{2}{\sqrt{3\lambda R}}$$

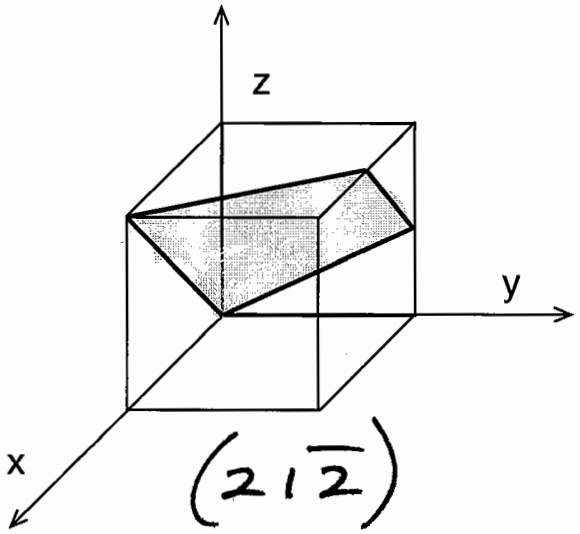
$$\therefore Z = 1 + \frac{2}{\sqrt{3\lambda R}}$$

$$= 1 + \frac{2}{(3 \times 1.80 \times 10^{-11} \times 1.1 \times 10^{7})^{1/2}} = 83$$

$\therefore$ The impurity is Bi

Problem #2 (24%)





(a) Using proper crystallographic notation, identify the direction and the plane depicted in the above sketches.

(8%)

(b) The figure below shows the unit cell of the compound A_xB_y. The dark spheres represent atoms of B.

(i) Name the Bravais lattice of A_xB_y. SC

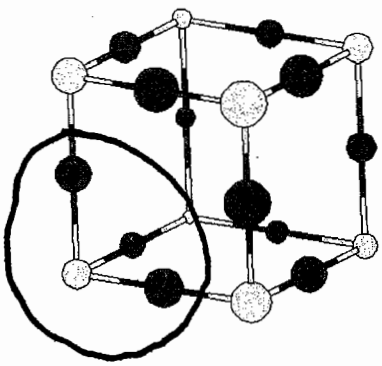
(4%)

(ii) Identify the basis of the crystal structure of A_xB_y. AB_3

(4%)

(iii) Determine the chemical formula of A_xB_y. Show your reasoning.

(8%)



basis

unit cell is space filling element

∴ Stoichiometry of U.C.

= Stoichiometry of Compound

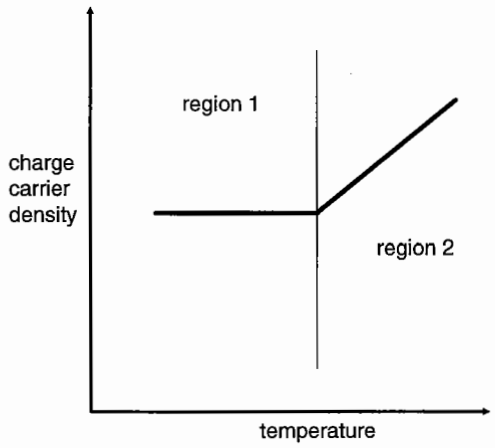
U.C. contains $8 \times \frac{1}{8}$ A atoms = 1

U.C. contains $12 \times \frac{1}{4}$ B atoms = 3

$\Rightarrow AB_3$

Problem #3 (24%)

(a) The figure below shows the temperature dependence of charge carrier density in germanium (Ge) doped with phosphorus (P). Explain the dominant process associated with the generation of charge carriers (i) in region 1 and (ii) in region 2.



(12%)

① carrier density independent of T
∴ extrinsic ≡ controlled by impurities
P donor contributes e^- to C.B.

② intrinsic ⇒ Thermal excitation of e^-s into C.B. leaving holes h^+ in V.B.

(b) The concentration of dopant can be on the order of $10^{17}/cm^3$, yet the energy of all these impurities is represented by a single level as opposed to a band. Explain why this is not a violation of the Pauli Exclusion Principle.

(6%)

Even at such concentrations, impurities are far enough apart that each can be viewed as separate quantum systems

(c) Explain the trend in the value of the wavelength of the absorption edge in the following homologous series: InSb, InAs, InP.

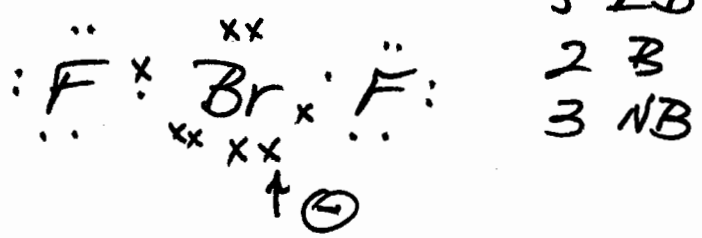
(6%)

stronger bonds as size of nonmetal decreases
∴ greater E_g
as E_g ↑, $\lambda_{abs\ edge}$ ↓

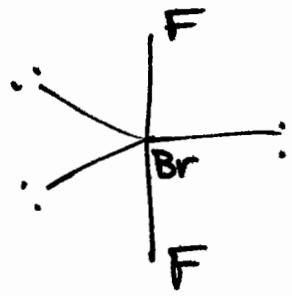
Problem #4 (32%)

(a) Draw a 3-dimensional representation of the molecular geometry around the central atom (not simply the Lewis structure) of BrF_2^-.

(8%) put more electropositive element at center



5 ED
2 B
3 NB



F–Br–F

(b) Name the type of hybrid orbitals that the central atom forms.

(2%) sp^3d

(c) Is the molecule polar or nonpolar? Justify. nonpolar

(4%) symmetric molecule — no net charge displacement

(d) For each pair of compounds, identify the one with the ***higher*** boiling point. Justify your choice.

(i) HCl and Ar HCl is polar; Ar nonpolar ⇒ van der Waals bonding

(18%) HCl intermolecular bonding is dipole–dipole which is stronger than van der Waals bonding at comparable volume

(ii) HF and LiF LiF is ionic ⇒ strong bonds — high lattice energy
HF is covalent — weak allowing for H-bonding, HF is no match for coulombic forces operating in LiF

(iii) MgO and CaO both ionic with common anion
Mg^{2+} & Ca^{2+} same valence but Mg^{2+} is smaller
∴ Mg–O bond distance is shorter
∴ stronger coulombic force of attraction
∴ higher lattice energy
∴ higher b.p.