Problem #1 (20%)

(a) Estimate the value of the screening factor in Moseley's Law associated with the M_α line. Show your reasoning.

(8%) – M_α lines generated by e^- transitions from $n=4 \rightarrow n=3$

– max. no. electrons capable of contributing to screening +ve charge of nucleus from n=4 is

$2 (n=1) + 8(n=2) + 18(n=3) = 28$

less at least 1 to create vacancy in M-shell

$\therefore \sigma_{M_\alpha} \leq 27$

(b) You suspect that aluminum you purchased from a recycling facility has been contaminated with a heavy metal. The x-ray emission spectrum of your metal reveals the presence of a K_α line at $\lambda = 1.85 \times 10^{-11}$ m. What is the impurity?

(12%) use Moseley's Law

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

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

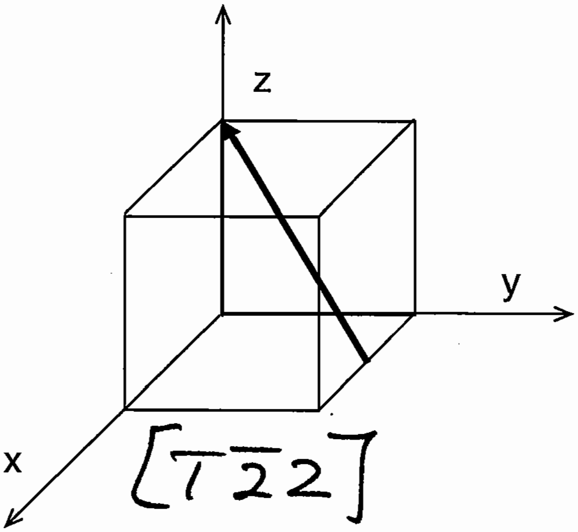
$$\therefore Z-1 = \frac{2}{\sqrt{3\lambda R}}$$

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

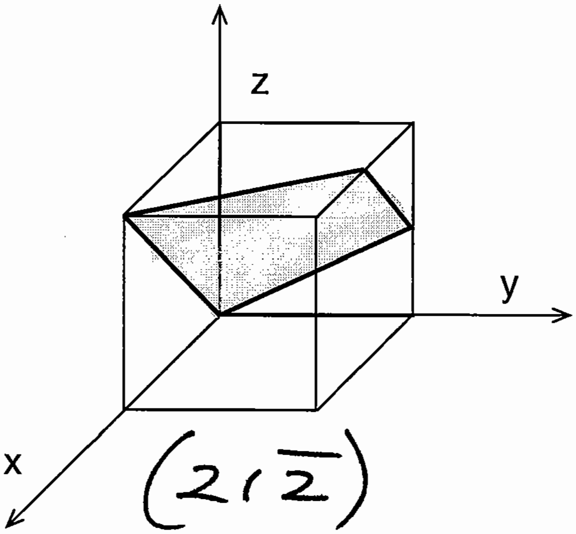
$$= 1 + \frac{2}{(3 \times 1.85 \times 10^{-11} \times 1.1 \times 10^{+7})^{1/2}}$$

$$= 82 \Rightarrow \underline{\underline{Pb}}$$

Problem #2 (24%)



[$\bar{1}\bar{2}2$]



($21\bar{2}$)

(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

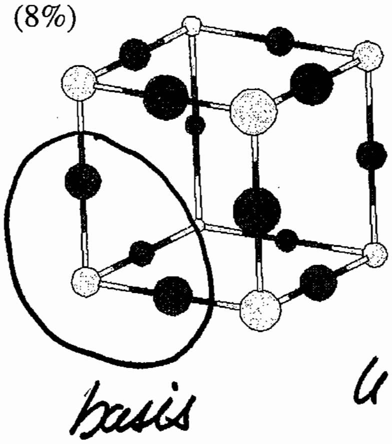
(4%)

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

(4%) AB_3

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

(8%)



unit cell is space filling element

∴ stoichiometry of u.c.

= stoichiometry of compound

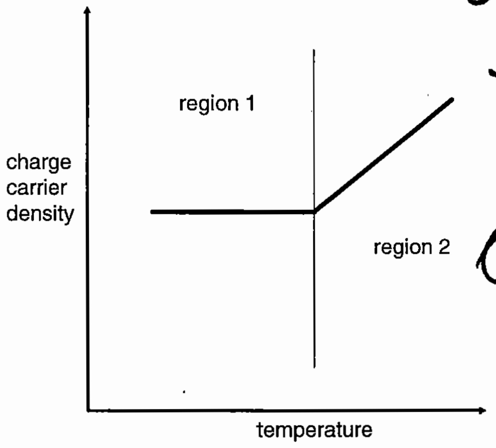
u.c. contains $8 \times \frac{1}{8}$ A atoms = 1

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 boron (B). Explain the dominant process associated with the generation of charge carriers (i) in region 1 and (ii) in region 2.



① Carrier density independent of T ∴ extrinsic ≡ controlled by impurities B contributes h^+s to v.b.

② intrinsic ⟹ Thermal excitation of e^-s into c.b. leaving h^+s in v.b.

(12%)

(b) The concentration of dopant can be on the order of $10^{17}/\text{cm}^3$, 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: CdS, CdSe, CdTe.

→

(6%)

weaker bonds as size of nonmetal increases

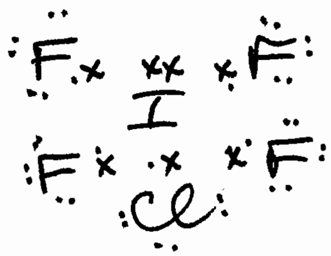
∴ smaller E_g

as E_g ↓, $\lambda_{\text{abs edge}}$ ↑

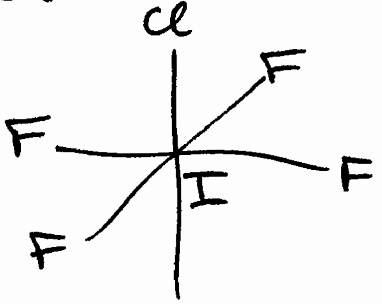
Problem #4 (32%)

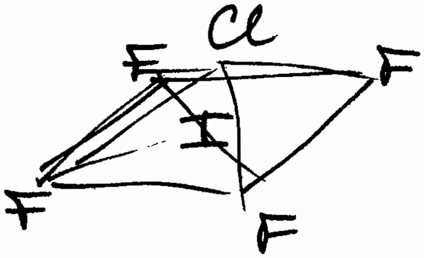
(a) Draw a 3-dimensional representation of the molecular geometry around the central atom (not simply the Lewis structure) of $ICl F_4$.

(8%) put most electropositive element at center



6ED
5B
1 NB





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

(2%) sp^3d^2

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

(4%) asymmetric molecule — net charge displacement along Cl — I — : axis

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

(i) $SnCl_4$ and [✓ $SbCl_3$] $SnCl_4$ is nonpolar ∴ van der Waals bonding

(18%) operative $SbCl_3$ is polar ∴ dipole-dipole interactions operative — at comparable volume the latter is stronger

(ii) HBr and [✓ LiBr] HBr is covalent & polar ∴ dipole-dipole interactions operative; LiBr is ionic — Coulombic forces lead to much stronger bonding

(iii) [✓ CuO] and CuS both ionic with common cation

O^{2-} & S^{2-} Same valence but O^{2-} is smaller

∴ Cu–O bond distance is shorter

∴ stronger coulombic force of attraction

∴ higher lattice energy

∴ higher b.p.