EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 4 (Spring 2025)

Name KEY A

Instructions: Open book/notes. Place answers in indicated spaces and show all work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A sample of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.79×10^6 #/cm^3 and a band gap of 1.424 eV at 300 K. It is doped with tellurium at a concentration of 2×10^{14} #/cm^3. Is the sample a p-type or n-type extrinsic semiconductor? Find the conduction band electron concentration n_0 (#/cm^3) and valence hole concentration p_0 (#/cm^3). Calculate the **magnitude** of the difference between the intrinsic Fermi energy and the Fermi energy of the sample in eV, i.e., $\Delta E = |E_F - E_{Fi}|$. Is E_F bigger or smaller than E_{Fi}?

Tellurium (Te) is a column to the right of arsenic (As) on periodic table $\Rightarrow$ donor $\Rightarrow$ **n-type**

Given that $N_d = 2\times10^{14}$ #/cm^3 >> $n_i = 1.79\times10^6$ #/cm^3 and $N_a = 0$, $\boldsymbol{n_0 \cong N_d = 2\times10^{14}}$ **#/cm^3**.

Or, can use (4.60),

$$n_0 = \frac{N_d - N_a}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2} = \frac{2\times10^{14} - 0}{2} + \sqrt{\left(\frac{2\times10^{14} - 0}{2}\right)^2 + \left(1.79\times10^6\right)^2}$$ to get

$\Rightarrow$ $\boldsymbol{n_0 \cong N_d = 2\times10^{14}}$ **#/cm^3**.

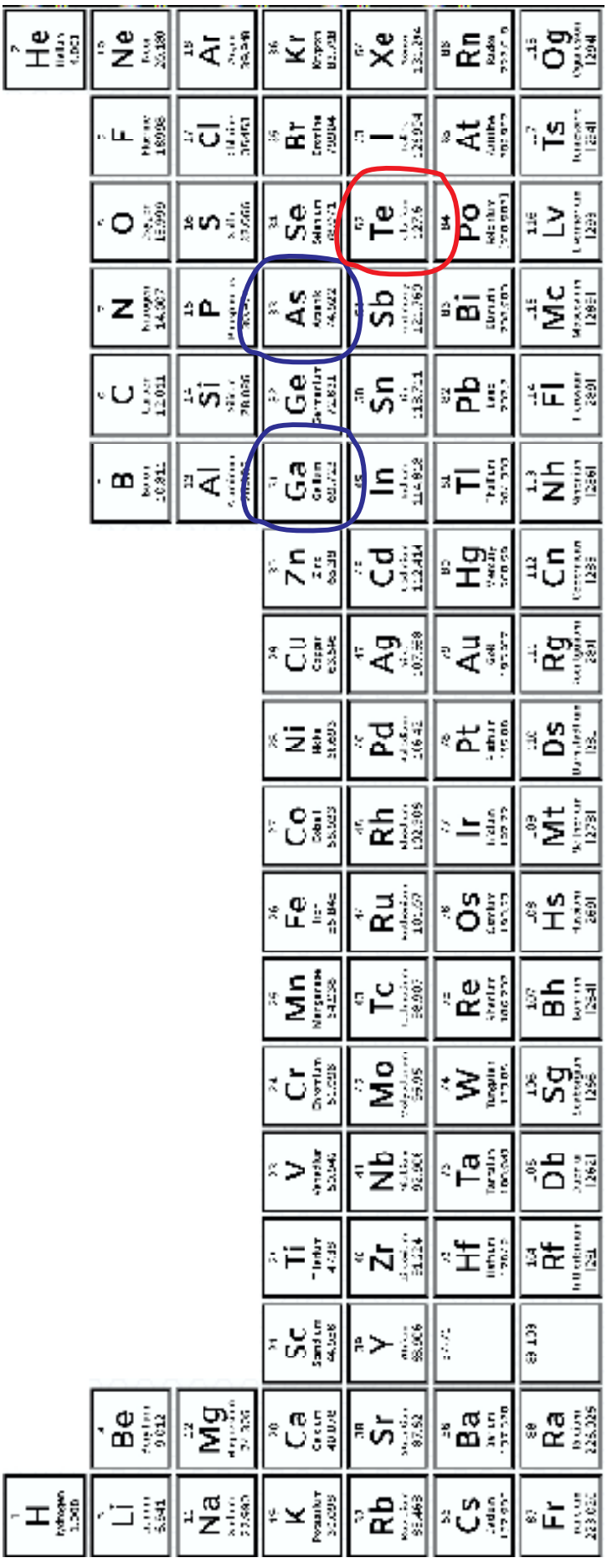
Per (4.43), $n_i^2 = n_0 p_0$ $\Rightarrow$ $p_0 = n_i^2 / n_0 = (1.79\times10^6)^2/2\times10^{14} \Rightarrow$ $\boldsymbol{p_0 = 0.0160205}$ **#/cm^3**.

Per (4.65), $E_F - E_{Fi} = k_B T \ln\left(\frac{n_0}{n_i}\right) = 8.617333\times10^{-5}(300)\ln\left(\frac{2\times10^{14}}{1.79\times10^6}\right)$

$\Rightarrow$ $\boldsymbol{\Delta E = |E_F - E_{Fi}| = 0.47908}$ **eV**.

p-type or **n-type** ? (circle correct) $n_0 = \boldsymbol{N_d = 2\times10^{14}}$ **#/cm^3** $p_0 = \boldsymbol{0.0160205}$ **#/cm^3**

$\Delta E = \boldsymbol{0.47908}$ **eV** $\boldsymbol{E_F > E_{Fi}}$ or $E_{Fi} > E_F$? (circle correct)



EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 4 (Spring 2025)

Name ___**KEY B**___

Instructions: Open book/notes. Place answers in indicated spaces and show all work for credit. Carry *at least* **6** significant figures on constants/parameters in calculations. Give answers with **4-5** significant figures.

A sample of gallium arsenide (GaAs) has an intrinsic carrier concentration of 1.79×10^6 #/cm^3 and a band gap of 1.424 eV at 300 K. It is doped with cadmium at a concentration of 6×10^{14} #/cm^3. Is the sample a p-type or n-type extrinsic semiconductor? Find the conduction band electron concentration n_0 (#/cm^3) and valence hole concentration p_0 (#/cm^3). Calculate the **magnitude** of the difference between the intrinsic Fermi energy and the Fermi energy of the sample in eV, i.e., $\Delta E = |E_F - E_{Fi}|$. Is E_F bigger or smaller than E_{Fi}?

Cadmium (Cd) is a column to the left of Gallium (Ga) on periodic table $\Rightarrow$ acceptor $\Rightarrow$ **p-type**

Given that $N_a = 6 \times 10^{14}$ #/cm^3 >> $n_i = 1.79 \times 10^6$ #/cm^3 and $N_d = 0$, $\boldsymbol{p_0 \cong N_a = 6 \times 10^{14}}$ **#/cm^3**.

Or, can use (4.62),

$$p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2} = \frac{6\times10^{14} - 0}{2} + \sqrt{\left(\frac{6\times10^{14} - 0}{2}\right)^2 + \left(1.79\times10^{6}\right)^2}$$ to get

$\Rightarrow$ $\boldsymbol{p_0 \cong N_a = 6 \times 10^{14}}$ **#/cm^3**.

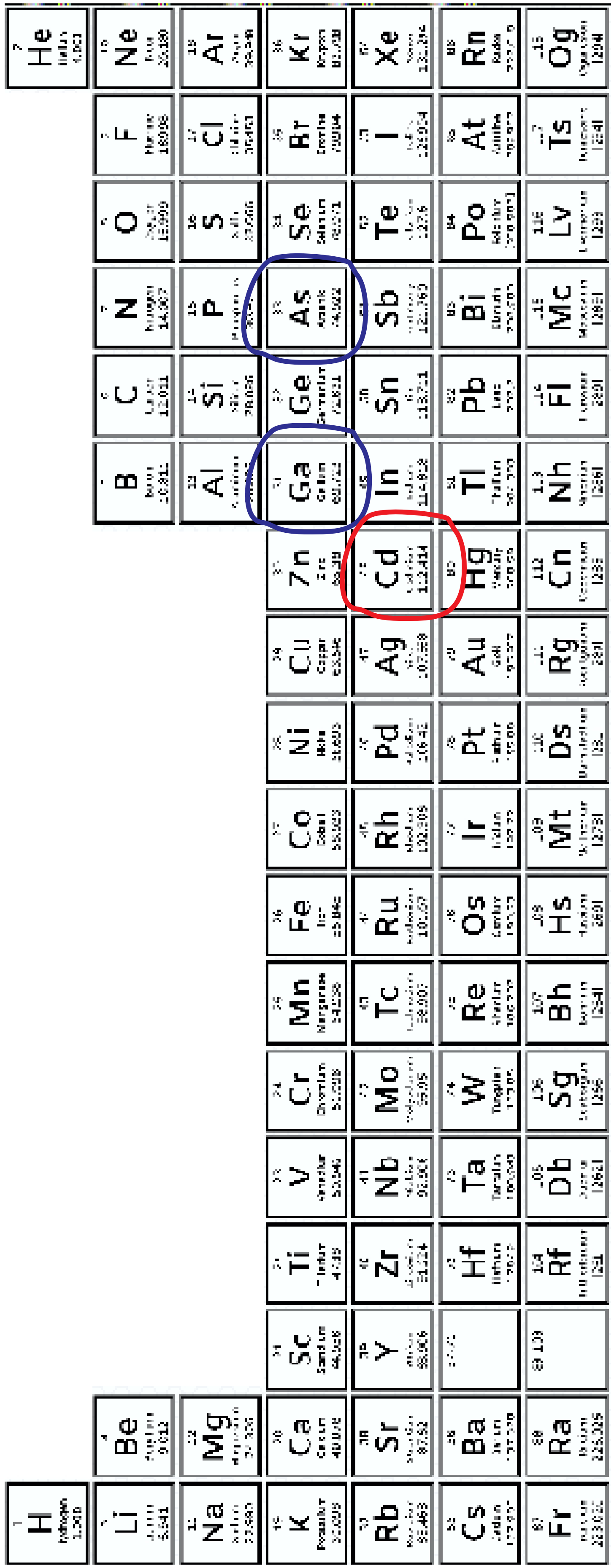
Per (4.43), $n_i^2 = n_0 p_0$ $\Rightarrow$ $n_0 = n_i^2 / p_0 = (1.79 \times 10^6)^2 / 6 \times 10^{14}$ $\Rightarrow$ $\boldsymbol{n_0 = 0.0053402}$ **#/cm^3**.

Per (4.68), $E_{Fi} - E_F = k_B T \ln\left(\frac{p_0}{n_i}\right) = 8.617333\times10^{-5}(300)\ln\left(\frac{6\times10^{14}}{1.79\times10^{6}}\right) = 0.50748055$

$\Rightarrow$ $\boldsymbol{\Delta E = |E_F - E_{Fi}| = 0.50748}$ **eV**.

p-type or n-type ? (circle correct) $n_0 =$ **0.0053402 #/cm^3** $p_0 =$ **6×10^{14} #/cm^3**

$\Delta E =$ **0.50748 eV** $E_F > E_{Fi}$ or **$E_{Fi} > E_F$** ? (circle correct)


H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Rf Db Sg Bh Hs Mt Ds Rg Cn Nh Fl Mc Lv Ts Og