4.46 (*a*) Silicon at $T = 300$ K is uniformly doped with boron atoms to a concentration of 3×10^{16} cm^{-3} and with arsenic atoms to a concentration of 1.5×10^{16} cm^{-3}. Is the material n type or p type? Calculate the thermal equilibrium concentrations of majority and minority carriers. (*b*) Additional impurity atoms are added such that holes are the majority carrier and the thermal equilibrium concentration is $p_0 = 5 \times 10^{16}$ cm^{-3}. What type and concentration of impurity atoms must be added? What is the new value of n_0?

a) From Table 4.3, boron is an acceptor while arsenic is a donor.

$N_a = 3\times10^{16}\ \#/cm^3 > N_d = 1.5\times10^{16}\ \#/cm^3 \Rightarrow$ **p-type**

Per Table B.4, $n_i = 1.5\times10^{10}\ \#/cm^3$ @ 300K

(4.62) $$p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a-N_d}{2}\right)^2 + n_i^2}$$

$$= \frac{(3-1.5)\times10^{16}}{2} + \sqrt{\left(\frac{1.5\times10^{16}}{2}\right)^2 + (1.5\times10^{10})^2}$$

$$p_0 = 1.5\times10^{16}\ \#/cm^3 = 1.5\times10^{22}\ \#/m^3$$

(4.43) $$n_0 = \frac{n_i^2}{p_0} = \frac{(1.5\times10^{10})^2}{1.5\times10^{22}}$$

$$n_0 = 1.5\times10^{4}\ \#/cm^3 = 1.5\times10^{10}\ \#/m^3$$

b) In (4.62), we saw that n_i is negligible. To achieve $p_0 = 5\times10^{16}\ \#/cm^3 > 1.5\times10^{16}\ \#/cm^3$, we must add more acceptors (boron).

$$p_0 = 5\times10^{16} = \Delta N_a + 3\times10^{16} - 1.5\times10^{16}$$

$$\hookrightarrow \Delta N_a = 3.5\times10^{16}\ \#/cm^3 = 3.5\times10^{22}\ \#/m^3$$

$$n_0 = \frac{(1.5\times10^{10})^2}{5\times10^{16}} \Rightarrow n_0 = 4.5\times10^{3}\ \#/cm^3 = 4.5\times10^{9}\ \#/m^3$$