3.091 Fall Term 2004

Homework #10

solution outlines

1. Assume steady state.

$$J = -D\frac{\Delta c}{\Delta x};\ \therefore\ \Delta x = D\frac{\Delta c}{J} = \frac{3.091\times10^{-4}\frac{\text{cm}^2}{\text{s}}\times1.5\times10^{19}\frac{\text{atom}}{\text{cm}^3}}{10^{-3}\frac{\text{mol}}{\text{cm}^2\,\text{hr}}\times\frac{1\text{ hr}}{3600\text{ s}}\times6.02\times10^{23}\frac{\text{atom}}{\text{mol}}} = \mathbf{2.773\times10^{-2}\ cm}$$

2. A solution to Fick's second law for the given boundary conditions is:

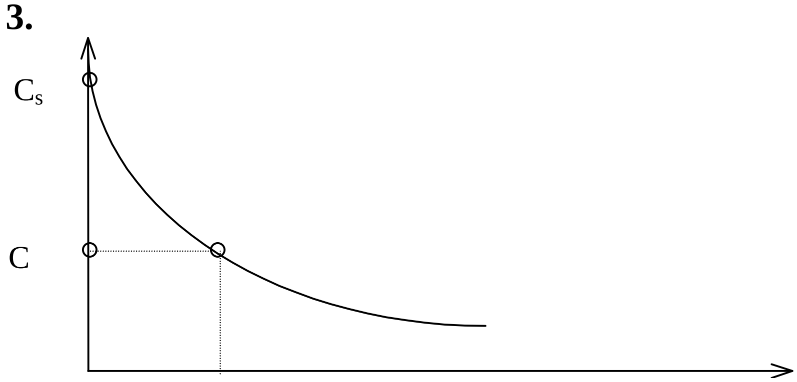
$$\frac{c}{c_s} = 1 - erf\frac{x}{2\sqrt{Dt}}\text{, from which we get}\qquad erf\frac{x}{2\sqrt{Dt}} = 1 - 0.018 = 0.982$$

From the error function tables 0.982 is the *erf* of 1.67. This means that $\frac{0.002}{2\sqrt{Dt}} = \frac{0.001}{\sqrt{Dt}} = 1.67$

$$D = D_0\cdot e^{\frac{-286\cdot10^5}{8.314\cdot1253}} = 6.45\cdot10^{-13}\ \frac{\text{cm}^2}{\text{sec}}$$

$$\therefore\ \mathbf{t = \frac{0.001^2}{1.67^2\cdot6.45\cdot10^{-13}} = 5.56\cdot10^5\ sec = 6.4\ days}$$

3.



$$\frac{c}{c_s} = erfc\frac{x}{2\sqrt{Dt}} = erfc\frac{3\times10^{-3}}{2\sqrt{Dt}} = erfc(2.083)$$

$$\frac{c}{c_s} = 1 - erf(2.083),\qquad \therefore 1 - \frac{c}{c_s} = 0.9964$$

$$\frac{c}{c_s} = 3.6\times10^{-3},\qquad \therefore c = 2.88\times10^{16}\ cm^{-3}$$

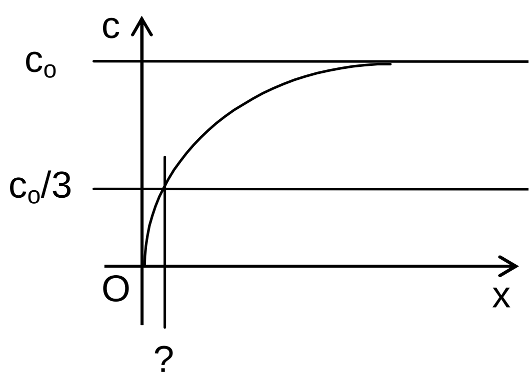
The donor concentration in germanium is $\mathbf{2.88\times10^{16}/cm^3}$.

4. $c(x,t) = c_s - c_s \text{ erf } \frac{x}{2\sqrt{Dt}} = c_s \text{ erfc} \frac{x}{2\sqrt{Dt}} \;=\; 5 \times 10^{16} \;=\; c_s \text{ erfc} \frac{25\times10^{-4}}{2\sqrt{7.23\times10^{-9}\times90\times60}}$

$$\therefore\ c_s \;=\; \frac{5\times10^{16}}{\text{erfc}\dfrac{25\times10^{-4}}{2\sqrt{7.23\times10^{-9}\times5400}}} \;=\; 6.43\times10^{16}\ cm^{-3}$$

erfc(0.20) = 1 – erf(0.20) = 1 – 0.2227 **= 0.7773**

5.



$$c(x,t) \;=\; c_0 \text{ erf } \frac{x}{2\sqrt{Dt}}$$

What is x when c = $c_o/3$?

$\frac{c_0}{3} = c_0 \text{ erf} \frac{x}{2\sqrt{Dt}} \Rightarrow 0.33 = \text{erf} \frac{x}{2\sqrt{Dt}}$; erf (0.30) = 0.3286 $\approx$ 0.33

$\therefore\ \frac{x}{2\sqrt{Dt}} = 0.30 \quad \therefore x \;=\; 2\times0.30\times\sqrt{3.091\times10^{-6}\times10\times60} \;=\; 2.58\times10^{-2}$ cm **= 258 μm**