Conduction in Ionic Materials

18.47   We are asked in this problem to determine the electrical conductivity for the nonstoichiometric $Fe_{(1 - x)}O$, given $x = 0.040$ and that the hole mobility is 1.0 x 10^{-5} m^2/V-s. It is first necessary to compute the number of vacancies per cubic meter for this material. For this determination let us use as our basis 10 unit cells. For the sodium chloride crystal structure there are four cations and four anions per unit cell. Thus, in ten unit cells of FeO there will normally be forty O^{2-} and forty Fe^{2+} ions. However, when $x = 0.04$, $(0.04)(40) = 1.6$ of the Fe^{2+} sites will be vacant. (Furthermore, there will be 3.2 Fe^{3+} ions in these ten unit cells inasmuch as two Fe^{3+} ions are created for every vacancy). Therefore, each unit cell will, on the average contain 0.16 vacancies. Now, the number of vacancies per cubic meter is just the number of vacancies per unit cell divided by the unit cell volume; this volume is just the unit cell edge length (0.437 nm) cubed. Thus

$$\frac{\# \text{ vacancies}}{m^3} = \frac{0.16 \text{ vacancies/unit cell}}{(0.437 \times 10^{-9} \text{ m})^3}$$

$$= 1.92 \text{ x } 10^{27} \text{ vacancies/m}^3$$

Inasmuch as it is assumed that the vacancies are saturated, the number of holes (p) is also 1.92 x 10^{27} m^{-3}. It is now possible, using Equation 18.17, to compute the electrical conductivity of this material as

$$\sigma = p|e|\mu_h$$

$$= (1.92 \times 10^{27} \text{ m}^{-3})(1.602 \times 10^{-19} \text{ C})(1.0 \times 10^{-5} \text{ m}^2/\text{V-s}) = 3076 \ (\Omega \text{-m})^{-1}$$