Exercise 6

In this exercise, you will have a deeper look into the Shockley-Read-Hall recombination process. In equations 2.5 and 2.6 of Shockleys paper[1] the following expressions (though in different notation) are given for the electron capture rate $\mathrm{d}r_\mathrm{a}$ and for the electron emission rate $\mathrm{d}r_\mathrm{b}$:

$$\mathrm{d}r_\mathrm{a} = c(E_\mathrm{t}) \cdot g(E) f(E) \cdot N_\mathrm{t} \left[1 - f(E_\mathrm{t})\right] \mathrm{d}E \tag{1}$$

$$\mathrm{d}r_\mathrm{b} = e(E_\mathrm{t}) \cdot N_\mathrm{t} f(E_\mathrm{t}) \cdot g(E) \left[1 - f(E)\right] \mathrm{d}E \quad \text{with} \tag{2}$$

$$f(E) = \frac{1}{1 + e^{\frac{E - E_\mathrm{F}}{kT}}} \quad \text{in thermal equilibrium.} \tag{3}$$

a) Explain in your own words the physical meaning and the dependencies of each parameter in equations (1) to (3).

b) Give the units of each parameter in equations (1) to (3).

c) Derive the equation

$$\frac{e(E_\mathrm{t})}{c(E_\mathrm{t})} = e^{\frac{E_\mathrm{t} - E}{kT}} \tag{4}$$

from equations (1) to (3) in thermal equilibrium.

[1] W. Shockley, W.T. Read, Phys. Rev. 87(5), 1952