Problem 1

A fine-grained polycrystalline Al sample with a narrow grain size distribution is quickly (instantaneously) quenched from a higher temperature T_i to a lower temperature T_f. The time dependence of the vacancy concentration is then monitored while keeping temperature at T_f and the characteristic time τ required for the vacancy concentration to achieve its equilibrium value at T_f is obtained. The size of the grains in the sample is small and it can be assumed that the grain boundaries are the main sinks/sources of vacancies.

(A) Using the values of parameters characterizing the self-diffusion in Al given in page 17 of the lecture notes Kinetics.pdf, perform an order of magnitude estimation of the value of time τ for T_f = 700 K and the characteristic grain size in the sample equal to 1 μm.

(B) What is the scaling law that describes the dependence of time τ on the grain size?

How the time τ would change if the grain size in the sample would change from 1 μm to 2 μm?

Problem 2

Nitrogen-hardened titanium alloys are used for hip implants in humans. The surface of a titanium sample is typically hardened by exposing it to a nitrogen-containing atmosphere and allowing nitrogen diffusion into the surface region. The optimum hardness is realized when a nitrogen concentration of 10^{-4} g/cm^3 is obtained at a depth of 10 μm.

You performed one experiment in which you exposed a surface of an initially nitrogen-free titanium sample (Ti sheet of thickness that is so large that the diffusion is not affected by the presence of the back surface) to the nitrogen atmosphere so that the nitrogen concentration at the surface of the titanium sample is maintained at 2×10^{-4} g/cm^3 during the experiment. You kept the Ti sample in the nitrogen atmosphere for 1 hour at a temperature of 500 K. After analysis of the sample you found that the concentration at a depth of 10 μm is 1.5×10^{-4} g/cm^3.

From your earlier experiments you know that the pre-exponential coefficient in the Arrhenius temperature dependence of the diffusion coefficient for nitrogen diffusion in titanium is $D_0 = 1$ cm^2/s.

How much should you change the temperature in this experiment (keeping all other parameters fixed) in order to obtain the optimum hardness?