Problem Set #2

Due Friday April 22, 2014 at 5pm

MS133: Kinetic Processes in Materials
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1. One hundred fleas are placed along the center line of a gymnasium floor at 6-in intervals. Twelve hours later the distance of each from the line is measured, and the sum of the squares of the distance divided by 100 is 36 in^2.

   (a) Calculate the diffusion coefficient of the fleas.

   (b) If the mean jump distance of a flea is equal to 0.1 in, estimate the mean jump frequency of the fleas.

   Now we repeat the experiment with a wind which pushes the fleas with velocity v in a direction perpendicular to the center line of the gymnasium.

   (c) Write down the equation for the flux of the fleas. Use the conservation equation to find the expression for Fick's second law in this case.

   (d) How will the sum of the squares of the distances be altered by the effect of the wind?

   (e) What are the physical situations of diffusion in solids which correspond to this second experiment?

2. In Sec. 2.6 we calculate the diffusion coefficient for the case of vacancy diffusion and obtain:

$$D = f a_0^2 \nu_0 \exp\left(\frac{\Delta S_M + \Delta S_\nu}{k}\right) \exp\left(\frac{-\Delta H_M - \Delta H_v}{kT}\right)$$

Calculate the equivalent expression for:

(a) Diffusion of an interstitial species which resides in the octahedral sites in a BCC metal.

(b) Interstitial mechanism in a BCC metal.

This will require using the general expression for diffusivity:

$$D = f(sa_0)^2 \nu p j z$$

and evaluating z, j, p, and s for these cases. Consider only nearest-neighbor jumps along the {100} type direactions. Tell whether there are correlation effects in either case, but do not bother evaluating f.

3. If at $t = 0$, N atoms of solute is located at the point $r = 0$ in a three-dimensional medium, the concentration of solute at any point r from the origin, after time t is:

$$c(r,t) = \frac{\gamma}{(4\pi Dt)^{3/2}}\ e^{-r^2/4Dt} \tag{2.18}$$

(a) Give the probability (normalized to 1) of finding an atom in a spherical shell dR thick and R from the center.

(b) What is the mean square value of R, that is, $\langle R^2 \rangle$, for the solute after time t?

(c) Using the results of part (b) and the random walk equation, $\langle R^2 \rangle = na^2$, show that:

$$D = \frac{1}{6}\Gamma a^2 \tag{2.19}$$

where $\Gamma = n/t$. Here a is the jump distance.

4. Consider a single line of atoms with one vacancy which can only jump forward or backward along the line. Calculate the correlation coefficient for atomic diffusion by a vacancy mechanism.