Collaborative Learning Exercise
Steady State Diffusion SOLUTIONS

Diffusion of plutonium through tank walls

Lead based tanks (with walls 10 cm thick) were designed to hold material contaminated with plutonium. The tanks were brought to a holding site for nuclear waste. Soil samples around the tank tested positive for plutonium. To show that plutonium was leaking through the tank, the sides of the tank were tested for plutonium.

- The atomic weight on plutonium is 244 g/mol
- The diffusion coefficient for plutonium through the tank material at the average temperature of the holding site is 1×10^{-15}cm^2/s.
- The concentration of plutonium in the tank walls was measured to be 0.5kg/cm^3 at 1 cm from the inside wall and 0.1kg/cm^3 at the 10 cm outside edge.

Question: What must the flux plutonium atoms through the tank wall be to cause the measured contamination levels in the wall? Give your answer in units of atoms/(cm^2 s). (We are assuming that this is a steady state problem. The concentration on the inside edge is kept constant by more diffusing out of the inside of the tank at atoms leave the tank wall (into the soil) on the other side.)

$$J = -D\left[\frac{C_A - C_B}{x_A - x_B}\right] = -1\times10^{-15}\,\frac{\text{cm}^2}{\text{s}}\left[\frac{0.5\frac{\text{kg}}{\text{cm}^3} - 0.1\frac{\text{kg}}{\text{cm}^3}}{1\text{cm} - 10\text{cm}}\right] = 4.44\times10^{-17}\,\frac{\text{kg}}{\text{cm}^2\text{s}}$$

$$= 4.44\times10^{-17}\,\frac{\text{kg}}{\text{cm}^2\text{s}}\,\frac{1\text{mol}}{244\text{g}}\,\frac{6.02\times10^{23}\text{atom}}{\text{mol}}\,\frac{1000\text{g}}{\text{kg}} = 1.095\times10^{8}\,\frac{\text{atoms}}{\text{cm}^2\text{s}}$$