1. The diffusion coefficient of glucose in water at 25 °C is 6.73\*10-10 m2s-1. Estimate the time required for a glucose molecule to undergo a root mean square displacement of 5.0 mm.

Assume independent motion on the direction in space.

Hint, you will need to make use of the Pythagorean theorem.

1. A dilute solution of KMnO4 in water at 25 °C was prepared. The solution was in horizontal tube of length 10 cm, and at first there was a linear gradation of intensity of the purple solution from the left (where the concentration was 0.100 mol dm-3) to the right (where the concentration was 0.050 mol dm-3). What is the magnitude and sign of the thermodynamic force acting on the solute close to the right face? Give the force per mole and force per molecule.

Useful equations and constants

R=8.14 J K-1 mol-1

$$\left〈x^{2}\right〉=2Dt$$

$$F=-\frac{RT}{c}×\frac{dc}{dx}$$

*N*A=6.02\*1023

Answers

1. $\left〈x^{2}\right〉=2Dt$ give the mean square distance travelled in any one dimension in time t. We need the distance travelled from a point in any direction. The distinction here is the distinction between the 1D and 3D diffusion. The mean square 3D distance can be obtained from the 1D mean square distance since motions in 3D are independent.

r2=x2+y2+z2 [Pythagorean theorem]

<r2>=<x2>+<y2>+<z2>=3<x2> [independent motion]

$\left〈x^{2}\right〉=2Dt$→$\left〈r^{2}\right〉=3×\left〈x^{2}\right〉=3×2Dt=6Dt$

Therefore , $t=\frac{\left〈r^{2}\right〉}{6D}=\frac{\left(5.0×10^{-3} m\right)^{2}}{6×6.73×10^{-10} m^{2}s^{-1}}=6.2×10^{3}s$

1. $F=-\frac{RT}{c}×\frac{dc}{dx}$

$\frac{dc}{dx}=\frac{\left(0.050-0.100\right) mol dm^{-3}}{0.10 m}=-0.50 mol dm^{-3} m^{-1}$ [linear gradation]

$$RT=2.48×10^{3} J mol^{-1}=2.48×10^{3} N m mol^{-1}$$

$F=-\frac{2.48×10^{3} N m mol^{-1}}{0.050 mol dm^{-3}}×\left(-0.50 mol dm^{-3} m^{-1}\right)=24.9 kN mol^{-1}$, or 4.1\*10-20 N molecule-1 (obtained through multiplication by Avogadro’s constant)