HW2

January 10, 2020

1 Chem 30324, Spring 2019, Homework 2

1.1 Due: January 29, 2020

1.2 Problem 1. Gases on a table top

In class we derived the properties of a 3-dimensional gas from the Boltzmann distribution and three postulates, and you studied a 1-dimensional gas in Homework 1. Suppose you were interested instead in a 2-dimensional gas, for example gas molecules able to freely skate around on a surface but that couldn't escape the surface.

1.2.1 1. Derive the Maxwell-Boltzman speed distribution for a 2-dimensional gas. (*Hint*: Think polar coordinates.)

1.2.2 2. Plot this 2-dimensional speed distribution for O_2 molecules at 200, 400 and 600 K.

1.2.3 3. Calculate the mean (expected value) of the speed of a 2-dimensional gas of molecules. How does your answer compare to a 3-dimensional gas?

1.2.4 4. Calculate the mean kinetic energy of a 2-dimensional gas. How does your answer compare to a one and 3-dimensional gas?

1.3 Problem 2. (Kinetics and Transport)

In junior Chemical Engineering laboratory, you will study the diffusion and solubility of CO_2 in an organic solvent using a diffusion cell like the one sketched here. Let's suppose that the gas space at the top of the diffusion cell is approximately 2 cm high and 4 cm in diameter. Further suppose that the gas in the head of the cell is pure CO_2 at 298 K and 1 bar pressure. Note that CO_2 has a collision diameter d of 0.40 nm.

1.3.1 **5. What does gas kinetic theory predict for the gas self-diffusion constant D_{11} of CO_2 gas in the cell, in cm^2s^{-1}?**

1.3.2 **6. Use the Stokes-Einstein relationship to estimate the diffusion constant of CO_2 in the Stoddard solvent. How does this compare with the diffusion constant in the gas phase? Why?**

1.3.3 **7. We found in class that the probability for a molecule to diffuse a distance x in time t is Gaussian with mean 0 and standard deviation $\sigma = \sqrt{2D_{11}t}$. About how long will it take for 1/3 of the molecules starting at the center of the gas space to diffuse all the way to the surface of the liquid, i.e., > 1 cm?**

1.3.4 **8. How many collisions on average does one of these diffusing CO_2 molecule make with other gas molecules on the way from the middle of the vapor space to the surface of the solvent?**

1.3.5 **9. How far in total distance does this typical CO_2 molecule travel in the time it takes to reach the solvent surface from the middle of the cell?**

1.3.6 **10. How many CO_2 molecules impinge on the surface of the Stoddard solvent in one second?**

1.3.7 **11. Using your estimate of the diffusion constant in the solvent, how long does it take the same fraction CO_2 molecules to diffuse a similar distance in 1-dimension in the liquid phase?**

1.3.8 **12. Is it safe to assume that any CO_2 that travels from the surface into the bulk of the solvent is rapidly replaced from the gas phase?**

1.3.9 **13. Suppose the volume of the gas-handling manifold is 100 cm^3 and is pressurized with CO_2 in the morning to 1.1 atm. What will the pressure in the manifold be four hours later, when lab starts, if the manifold has a pinhole of 1 m^2?**