Thermodynamics HW #2

September 6, 2019

1. Schroeder 1.11

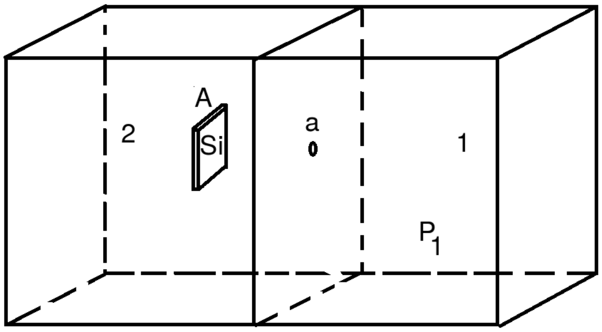

Figure 1: diagram of problem 2

2. *(lab inspired!)* Two vacuum chambers, both at room temperature, are separated by a wall containing a hole of area $a = 1\text{mm}^2$. Chamber 1 has a partial pressure of water of $P_1 = 10 \times 10^{-5}$ Pa. Chamber 2 houses a thin silicon sample of surface area $2A = 2\text{cm}^2$ and maintains an essentially perfect vacuum ($P_2 \approx 0$). Figure 1 may be helpful to refer to.

   Assume that any water molecule entering the second chamber via the hole strikes and sticks to (i.e. "adsorbs" onto) the large face of the silicon surface facing the hole. Let the silicon crystal be cut in such a way that the large faces have the (100) orientation, i.e. the vector perpendicular to the large faces are parallel with one of the edges of the silicon unit cell. When water sticks to Si(100) it is believed that it decomposes so that an OH is bonded to a surface silicon atom and the remaining H atom is bonded to a neighboring silicon atom[1].

   We would like to perform an experiment studying the clean silicon surface, so that there are few adsorbed molecules. Suppose we define the surface to be dirty when $> 10\%$ of the surface is covered in adsorbates. If we start with a clean silicon sample, so that there are initially no adsorbates, then how long do we have to perform our experiment before it becomes dirty? Assume that the mean velocity $\bar{v}$ of the water molecules can be approximated by $\sqrt{\overline{v^2}}$. Full credit awarded to answers correct within 50%.

3. Schroeder 1.26.

---

[1] Hossain, M. Z., Yamashita, Y., Mukai, K., & Yoshinobu, J. (2003). Model for C defect on Si(100): The dissociative adsorption of a single water molecule on two adjacent dimers. Physical Review B, 67(15), 153307. https://doi.org/10.1103/PhysRevB.67.153307

4. Schroeder 1.33 (you will need to assume that the internal energy U is equal to $cNkT$ for some positive constant c).

5. Schroeder 1.37. Prove to yourself that we can apply Schroeder equation (1.39) for *mixtures* of gas (e.g. 75% nitrogen + 25% argon, or 10% hydrogen + 10% oxygen + 80% methane, etc.) if we replace f with $\bar{f} = \sum_n f_n x_n$, where f_n and x_n are the degrees of freedom and mole fraction of the n^{th} component of the mixture respectively.

   Then try to determine a reasonable estimate for gas composition in the piston of a diesel engine and thus an estimate of $\bar{f}$.