1 Interstellar pressure

Interstellar space has about one H_2 molecule per cubic centimeter. The temperature of deep space is about 3 K. What is the pressure of this interstellar gas? How does it compare to the best vacuum we can achieve in the laboratory ($\sim 10^{-13}$ Pa)? How fast is the typical H_2 molecule moving in interstellar space (average speed)?

2 Helium heat capacity

In class, we assumed that all monatomic gases have 3 degrees of freedom ($f = 3$). In this question, we explore the possibility that a monatomic gas might have additional degrees of freedom due to the electrons orbiting the nucleus. To answer this question, you will need to use the equipartition theorem and understand how quantized energy levels affect the application of the equipartition theorem.

Helium is a monatomic gas at room temperature. An atom of helium can store energy by bumping its electron from its lowest orbital energy level to a higher orbital energy level. In particular, moving an electron from the lowest state to the first excited state would store an energy of 24.6 eV (24.6 electron-volts). Give a quantitative explanation (i.e. by comparing quantities) that shows we can ignore this energy storage mode when calculating the heat capacity of helium gas at ordinary temperatures.

3 Heating gas

Suppose we have two rigid containers, one holding N molecules of helium gas, and one holding $N/2$ molecules of oxygen gas. Both are initially at room temperature. We then add the same amount of energy to each gas by heating. Which gas is hotter at the end?