29.1: Introduction- Gases

A gas consists of a very large number of particles (typically 10^{24} or many orders of magnitude more) occupying a volume of space that is very large compared to the size (10^{-10} m) of any typical atom or molecule. The state of the gas can be described by a few macroscopically measurable quantities that completely determine the system. The volume of the gas in a container can be measured by the size the container. The pressure of a gas can be measured using a pressure gauge. The temperature can be measured with a thermometer. The mass, or number of moles or number of molecules, is a measure of the quantity of matter.

Macroscopic vs. Atomistic Description of a Gas

How can we use the laws of mechanics that describe the motions and interactions of individual atomic particles to predict macroscopic properties of the system such as pressure, volume, and temperature? In principle, each point-like atomic particle can be specified by its position and velocity (neglecting any internal structure). We cannot know exactly where and with what velocities all the particles are moving so we must take averages. In addition, we need quantum mechanical laws to describe how particles interact. In fact, the inability of classical mechanics to predict how the heat capacity of a gas varies with temperature was the first experimental suggestion that a new set of principles (quantum mechanics) operates at the scale of the size of atoms. However, as a starting point we shall use classical mechanics to deduce the ideal gas law, with only a minimum of additional assumptions about the internal energy of a gas.

Atoms, Moles, and Avogadro's Number

Avogadro's number was originally defined as the number of molecules in one gram of hydrogen. The number was then redefined to be the number of atoms in 12 grams of the carbon isotope carbon-12. The results of many experiments have determined that there are $6.02214129 \times 10^{23} \pm 0.00000027 \times 10^{23} \equiv 6.02214129(27) \times 10^{23}$molecules in one mole of carbon-12 atoms. Recall that the mole is a base unit in the SI system of units that is a unit for an amount of substance with symbol [mol]. The mole is defined as the amount of any substance that contains as many atoms as there are in 12 grams of carbon12. The number of molecules per mole is called the Avogadro constant, and is

$$N_A = 6.0221415 \times 10^{23} \mathrm{mol}^{-1}$$

As experiment improved the determination of the Avogadro constant, there has been a proposed change to the SI system of units to define the Avogadro constant to be exactly $N_A = 6.02214\mathrm{X} \times 10^{23} \mathrm{mol}^{-1}$ where the X means one or more final digits yet to be agreed upon. Avogadro's number is a dimensionless number but in the current SI system, the Avogadro constant has units of [mol^{-1}] and its value is equal to Avogadro's number.