Lecture 14: learning objectives

You will be able to state the properties of an ideal gas and apply the ideal gas law.

You will be able to state the assumptions of the kinetic theory of gases.

You will be able to relate the pressure and temperature to the average kinetic energy and define the internal energy of a gas.
Ideal gas

Ideal gas:
System containing a (very) large number of widely-separated point particles that interact only through perfectly elastic collisions.

Avogadro’s number:
The number of particles in one mole of a substance.

Avogadro’s number is given by
\[ N_A = 6.02 \times 10^{23} \text{ particles/mole} \]

Mole:
One mole of any substance is that amount of the substance that contains as many particles (atoms, molecules or other particles) as there are atoms in 12 g of the isotope carbon-12.
Ideal gas

Ideal gas law:
The product of the pressure and volume of an ideal gas is proportional to the number of moles of gas times the temperature of the gas.

$$PV = nRT$$

Here $R$ is the ideal gas constant, $R = 8.31$ J K/mol and $n$ is the number of moles of gas.

$$PV = Nk_B T$$

Here $k_B$ is Boltzmann’s constant $k_B = \frac{R}{N_A} = 1.38 \times 10^{-23}$ J/K and $N$ is the number of molecules.

The temperature $T$ must be measured in Kelvin!
Kinetic theory of gases

Pressure in the kinetic theory of gases:
The pressure of an ideal gas is proportional to the number of molecules per unit volume and to the average translational kinetic energy of a molecule.

\[ P = \frac{2}{3} \frac{N}{V} \left( \frac{1}{2} \bar{mv^2} \right) \]

Temperature in the kinetic theory of gases:
The temperature of an ideal gas is a direct measure of the average molecular kinetic energy of the gas.

\[ \frac{1}{2} \bar{mv^2} = \frac{3}{2} k_B T \]
Temperature in the kinetic theory of gases:
The temperature of an ideal gas is a direct measure of the average molecular kinetic energy of the gas.

\[ \frac{1}{2} m \bar{v}^2 = \frac{3}{2} k_B T \]

Root-mean-square speed:
The square root of the average of the speed-squared of each molecule.

\[ v_{\text{rms}} = \sqrt{\frac{3RT}{M}} \]

Here \( M \) is the molar mass in kilograms per mole.
Kinetic theory of gases

The total kinetic energy of N molecules is

\[ E_K^{\text{total}} = \frac{3}{2} nRT \]

Internal energy in the kinetic theory of gases:
The internal energy of a monatomic gas is given by the total kinetic energy of the molecules.

\[ U = \frac{3}{2} nRT \]