(sodium chloride, NaCl), which will have a mass of (1 x 23.0) + (1 x 35.5) or 58.5 grams. The molar mass of NaCl is 58.5 g/mol.

The Dependence of Kinetic Energy of Molecules on Temperature

The speed of a single, isolated, moving molecule determines its energy. Physics provides us with the equation: energy = $\frac{1}{2} mv^2$ for a moving particle of mass, m, and velocity, v. Physicists also determined that energy of motion is directly related to temperature, if temperature is determined on the Kelvin scale. So, the energy of a molecule = $3/2\ kT$, where T is the temperature of the gas (in K), and k is a universal constant known as the **Boltzmann constant**.

Since both expressions represent the same molecule's energy, we can put them together and do some algebra to give us an equation for an average molecule's speed, u:

$$u = \sqrt{\frac{3kT}{m}}.$$

Since this is derived by taking a square root, it is known as the "root mean square" speed. If we now consider N molecules, instead of just one, where N is Avogadro's Number, we have 1 mole of gas, and the mass becomes the mass of 1 mole of molecules, the molar mass, M. The Boltzmann constant can be recomputed for 1 mole of gas and given the symbol R, which is known as the "universal molar gas constant."

The equation for root mean square speed of molecules in a mole of gas is $u = \sqrt{\frac{3RT}{M}}$.

It is interesting to question how fast gas molecules are moving. If we apply this equation to helium atoms (such as might be in your birthday helium balloon on a warm day), put in a molar mass, M, of 4, and a temperature, T, of 298 K (25°C or 77°F), and get all the units correct, we find a root mean square speed of 1,360 meters per second. That's almost a mile per second!

The calculation looks like this:

$$u = \sqrt{\frac{3 \times 8.31\ kg \times m^2 \times s^{-2} \times mol^{-1} \times K^{-1} \times 298K}{4 \times 10^{-3}\ kg \times mol^{-1}}}$$

It is clear that the helium atoms inside the balloon are zipping backward and forward, making many thousands of trips across the balloon every second, bouncing off the walls, and creating the pressure inside the balloon.

The Ideal Gas Equation

If we now substitute the expression for u into the equation we worked out previously, namely $PV = \frac{1}{3} Mu^2$ (since $Nm = M$), we find:

$$PV = \tfrac{1}{3} M \text{ x } 3RT/M = RT$$

This equation is known as the universal gas equation, or the "**ideal gas equation**." We should keep in mind that here we have assumed 1 mole of gas. However, we can modify the equation easily for any number of moles of gas by including n moles, so $PV = nRT$.

Note that this has exactly the same form as the combined Boyles and Charles law equations for a fixed amount of gas, since R and n will be constant: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$. It was very satisfying to early physicists and chemists that they could model the behavior of gases by making the assumptions of kinetic-molecular theory and using equations for the motion of a particle.

CARL WILHELM SCHEELE, JOSEPH PRIESTLEY, ANTOINE LAVOISIER, AND THE DISCOVERY OF OXYGEN

Like many scientific discoveries, the discovery of oxygen was accomplished by multiple scientists working mostly independent of one another. Carl Wilhelm Scheele (1742–1786), a German Swedish chemist, is one of three scientists who is often credited with discovering oxygen. The timeline for Scheele's discovery is a bit murky since the results of his experiments were not published until 1777 even though he had been conducting his work in the early 1770s. Sometime around 1772 (perhaps as early as 1770), Scheele became the first scientist to produce O_2, which he referred to as "fire-air," by heating various oxides. Scheele observed that oxygen was odorless and tasteless and that it supported respiration and **combustion** better than air.[8]