Grahams' Law of Diffusion and Effusion

The **diffusion** is the *process of gradual mixing of molecules of one gas with molecules of another gas due to their molecular motion(kinetic energy).* The diffusion always proceeds from a region of high concentration to a region of lower concentration. For example, when a bottle of perfume is opened at one end of the room, the person sitting at the other end of the room can smell the perfume because of the diffusion process of perfume molecules.

Thomas Graham (1805-1861), the Scottish chemist, in 1832 (the photo is taken from http://en.wikipedia.org/wiki/Thomas_Graham_(chemist)) discovered that *under the same conditions of pressure and temperature, the rate of diffusion of a gas is inversely proportional to the square root of its molar mass.* The mathematical equivalent of this law is,

$$rate \, \alpha \, \frac{1}{\sqrt{M}}$$

where M is the molar mass of the gas. This equation is useful in qualitative way of understanding the relative rates of gases. For example, if you want to know, between H_2 and O_2, which gas has the higher rate of diffusion? Just by knowing the molar masses of these gases, it is possible to get some idea about their relative rates. The molar mass of H_2 is 2.0 g/mol and that is O_2 is 32.0 g/mol. Since the rate is inversely proportional to the molar mass, the H_2 gas has greater rate of diffusion than O_2. But, if you want to know by how much greater, then the above equation cannot be used in its form.

To compare the rates of two different gases, the above equation can be written as

$$\frac{rate_1}{rate_2} = \sqrt{M_2 \, / \, M_1}$$

Example

Find the ratio of diffusion rates of hydrogen gas and oxygen gas.

Answer

The Graham's laws for hydrogen gas and oxygen gas can be written as

$$\frac{rate_{H_2}}{rate_{O_2}} = \sqrt{M_{O_2} / M_{H_2}} = \sqrt{32/2} = \sqrt{16} = 4$$

This can be interpreted as the rate of hydrogen is four times the rate of oxygen.

$$rate_{H_2} = 4\,x\,rate_{O_2}$$

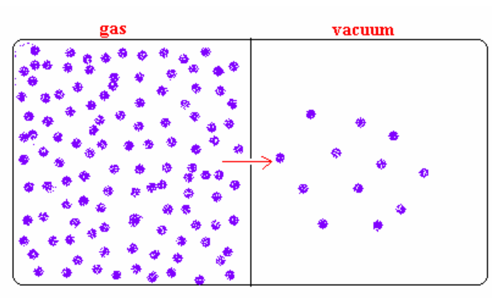
That means, the hydrogen has the speed four times greater than the speed of oxygen.

Word of Caution

Note that how the equation is set up. The rate of the lighter is in the numerator and that of the heavier gas is in the denominator and the molar mass of the heavier gas is in the numerator and that of lighter gas is in the denominator. If you set up this, the final answer will be greater than 1, which can be interpreted without any difficulty. However, if you set up the equation other way around, your final answer will be less than 1, which might be little difficult to interpret.

Effusion

The process of effusion is quite different than the process of diffusion. The effusion is the process of forcing a gas through a pin hole from one compartment to another empty (vacuum) compartment.



The Graham's law is also applicable to this situation. That means, the above given equation are equally valid for effusion process also.