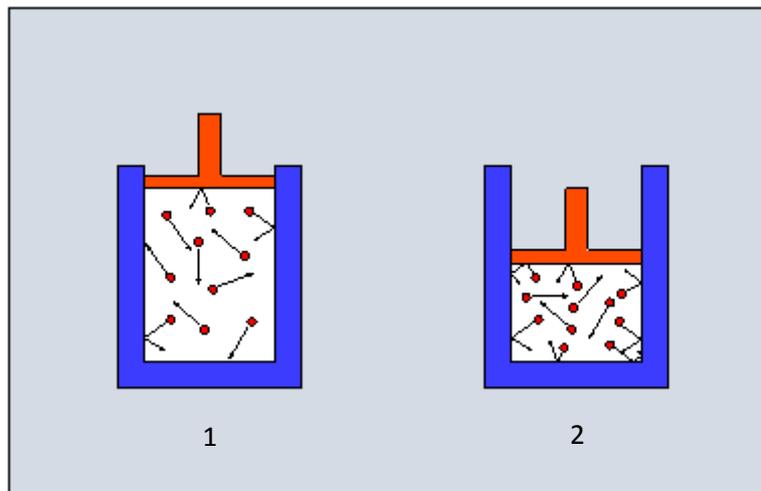


## LAWS OF IDEAL GAS

The following laws and equations are exact only for ideal gases; however, they represent a good approximation of the behavior of most gases under moderate pressure and temperature.

### Boyle's law

Boyle's law shows that, at constant temperature, the product of an ideal gas's pressure and volume is always constant.



If the volume is reduced, with a fixed amount of molecules inside, more molecules will hit the sides of the container per unit time, increasing the internal pressure.

Therefore, as a mathematical equation, Boyle's law is:

$$P_1V_1 = P_2V_2$$

so

$$PV = k$$

Where **P** is the pressure (Pa), **V** the volume (m<sup>3</sup>) of a gas, and **k** (measured in joules) is the constant from this equation.

### **Charles's law**

This law states that for an ideal gas at constant pressure, the volume is directly proportional to the absolute temperature (in kelvins).

$$V = kT$$

Where **T** is the absolute temperature of the gas (in kelvins) and **k** (in  $\text{m}^3 \cdot \text{K}^{-1}$ ) is the constant produced.

### **Gay-Lussac's law**

It states that the pressure exerted on a container's sides by an ideal gas is proportional to the absolute temperature of the gas. This follows from the kinetic theory—by increasing the temperature of the gas, the molecules' speeds increase meaning an increased amount of collisions with the container walls.

In mathematical terms, the Gay-Lussac's law is:

$$P = kT$$

### **Avogadro's law**

Avogadro's law states that the volume occupied by an ideal gas is proportional to the amount of moles (or molecules) present in the container. This gives rise to the molar volume of a gas, which at Standard conditions of temperature and pressure is  $22.4 \text{ dm}^3$  (or litres).

$$V = kn$$

Where **n** is equal to the number of moles of gas.

### **General law for ideal gases**

Combining the four laws the relationship between the pressure, volume, and temperature can be shown for a fixed mass of gas:

$$PV = nRT$$

Where the constant  $R$ , is the gas constant with a value of  $.08206 \text{ (atm}\cdot\text{L)/(mol}\cdot\text{K)}$

## **OTHER GAS LAWS**

### **Dalton's law**

Dalton's law of partial pressures states that the pressure of a mixture of gases simply is the sum of the partial pressures of the individual components. Dalton's Law is as follows:

$$P_{\text{total}} = P_1 + P_2 + P_3 + \dots + P_n$$

Where  $P_{\text{total}}$  is the total pressure of the mixture of gases, and  $P_n$  are the individual partial pressures of each of the gases of the mixture at the given temperature.

### **Henry's law**

Henry's law states that at a constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.

$$p = kc$$

Where  $p$  is the partial pressure of the solute in the gas above the solution,  $c$  is the concentration of the solute and  $k$  is a constant with the dimensions of pressure divided by concentration. The constant, known as the Henry's law constant, depends on the solute, the solvent and the temperature.

## **FLAW REGIMES**

Flaw regimes can be classified in three categories:

- 1) Viscous or laminar regime
- 2) Molecular regime
- 3) Transitional regime

### **Viscous or laminar regime**

It is characterized by a very orderly and uni-directional flow of the molecules, which move straight with no lateral mixing, cross currents or swirls. Under these conditions, when considering a circular section with gas or fluid running through, the flow is governed by Poisseuille's law:

$$Q = \frac{\pi r^4}{16\eta l} (p_1^2 - p_2^2)$$

Where **Q** is the flow, **r** is the radius of the section, **l** is the length of the section,  **$\eta$**  is the viscosity of the gas (or fluid),  **$p_1$**  is the inlet pressure and  **$p_2$**  is the outlet one.

### **Molecular regime**

This is the typical type of flow under vacuum conditions and it occurs when the probability of collision between molecules is lower than the probability of collision between molecules and walls. Under these conditions, the flow is not orderly and straight, but it is chaotic and with no prevailing direction. The equation governing this type of flow is:

$$Q = \frac{\sqrt{2}}{6} \pi \sqrt{\frac{RT}{M}} \frac{d^3}{l} (p_1 - p_2)$$

Where **Q** is the flow, **d** is the diameter of the section, **l** is the length of the section, **T** is the absolute temperature, **M** is the relative mass,  **$p_1$**  is the inlet pressure and  **$p_2$**  is the outlet one.

### **Transitional regime**

This type of regime includes characteristics of both the regimes previously described.

## **CLASSIFICATION OF VACUUM LEVELS AND RELATIVE FLOW REGIMES**

<i>Type of Vacuum</i>	<i>Pressure</i>	<i>Regime</i>
Rough	$1013\text{mbar} < p < 1\text{mbar}$	Laminar flow
Medium	$1\text{mbar} < p < 10^{-3}\text{mbar}$	Transition flow
High	$10^{-3}\text{mbar} < p < 10^{-6}\text{mbar}$	Molecular flow
Ultra High	$p < 10^{-6}\text{mbar}$	