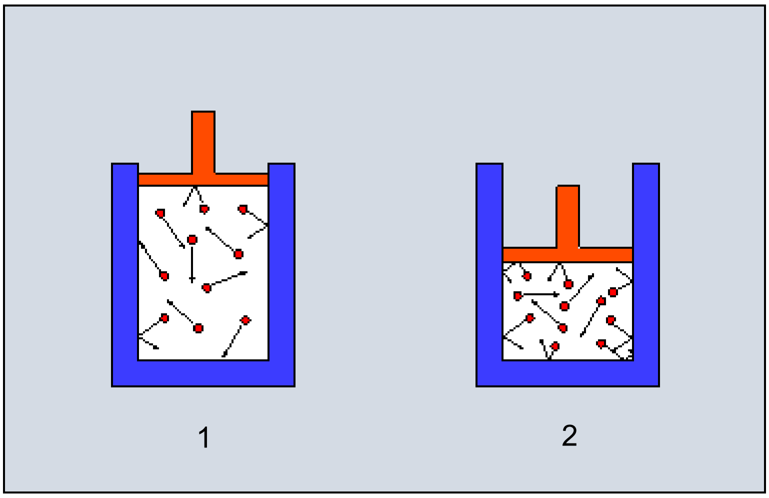
LAWS OF IDEAL GAS

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

$$\mathbf{PV = k}$$

Where **P** is the pressure (Pa), **V** the volume (m^3) 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 $m^3 \cdot K^{-1}$) 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 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 (atm·L)/(mol·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:

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

Where P_{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, η is the viscosity of the gas (or fluid), $\mathbf{p_1}$ is the inlet pressure and $\mathbf{p_2}$ 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, $\mathbf{p_1}$ is the inlet pressure and $\mathbf{p_2}$ 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

Type of Vacuum	*Pressure*	*Regime*
Rough	1013mbar < p < 1mbar	Laminar flow
Medium	1mbar < p < 10^{-3} mbar	Transition flow
High	10^{-3} mbar < p < 10^{-6} mbar	Molecular flow
Ultra High	p < 10^{-6} mbar	