ALICAT SCIENTIFIC

PRESSURE & FLOW

Pressure and the ideal gas law

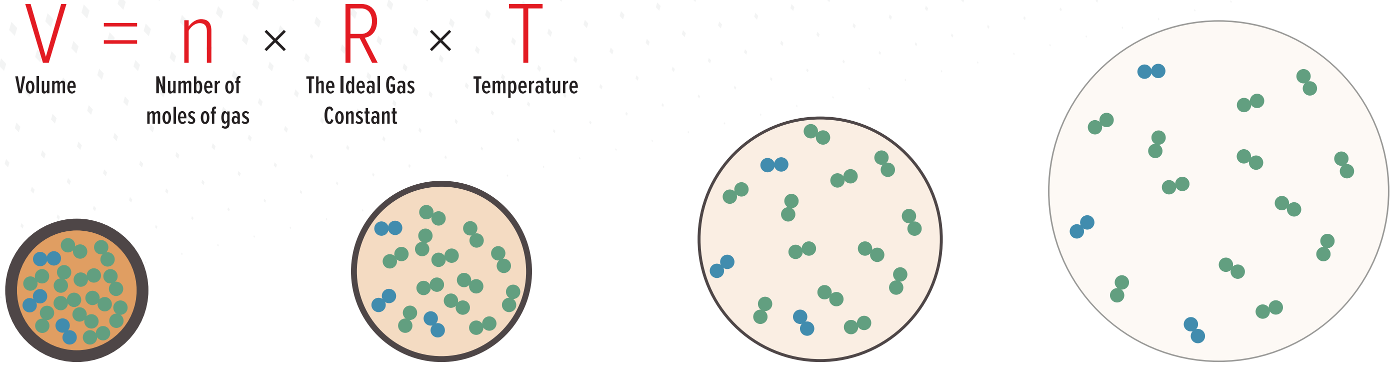
Pressure is a measure of the force exerted upon an object. Because gases are compressible, increasing pressure pushes the gas molecules closer together.

This causes the volume of gas to decrease. The relationship between the pressure and volume of a gas is expressed by the ideal gas law:

$$P \times V = n \times \bar{R} \times T$$

Pressure | Volume | Number of moles of gas | The Ideal Gas Constant | Temperature

Imagine a flexible container filled with 500 scm^3 of air at 1 atm (≈14.696 PSIA) and 25°C. If you compress the volume to 250 cm^3, the pressure will double to 2 atm. If you expand the volume to 1000 cm^3 or 2000 cm^3, the pressure will be reduced to 0.5 atm or 0.25 atm respectively. Because no air is added or removed during this process, the moles of air inside the container do not change from its original 500 scm^3 of air.



Air at 2 atm
Mass: *500 scm^3*
Volume: *250 cm^3*

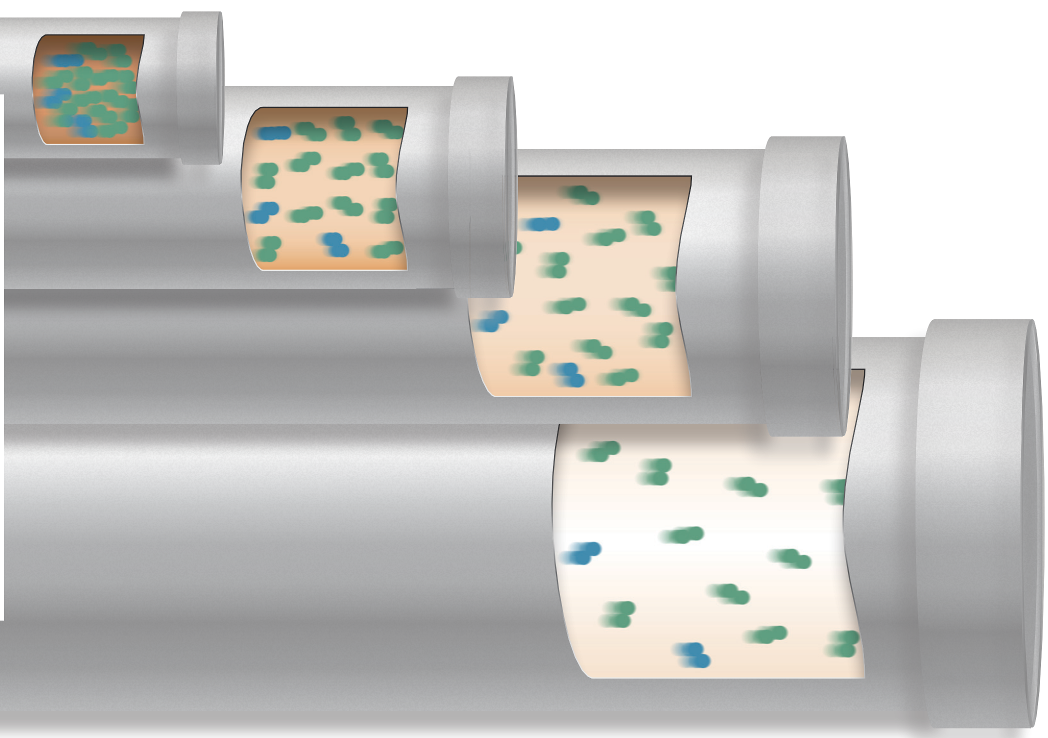
Air at 1 atm
Mass: *500 scm^3*
Volume: *500 cm^3*

Air at ½ atm
Mass: *500 scm^3*
Volume: *1 000 cm^3*

Air at ¼ atm
Mass: *500 scm^3*
Volume: *2 000 cm^3*

Effects of line pressure on mass and volumetric flow rates

When air is put into motion as a flow of gas, the actual space the air takes up per unit of time (volumetric flow rate) varies with pressure in the same manner as the static air. Doubling the line pressure halves the volumetric flow rate, and vice versa. However, the number of molecules of air that flow per unit of time (mass flow rate) does not change.



Mass flow vs true mass flow

The mass flow rates discussed on the previous page are actually standardized volumetric flow rates. The volumetric flow is "standardized" to a chosen temperature and pressure (in the previous examples 25°C and 1 atm). This mass flow rate tells what the volumetric flow rate would have been if the pressure and temperature had been equal to these standard values. It is given in standard units like Standard Liters Per Minute (SLPM) or Standard Cubic Feet per Minute (SCFM). On the other hand, true mass flow is given in weight per time, like grams/min. The true mass flow rate can be obtained by multiplying the mass flow rate by the gas density.

Standard/Normal Temperature and Pressure

As one might expect, comparing volumetric flow rates across experiments can become very difficult because pressure and temperature must remain constant. This is one of the main reasons scientists and engineers use mass flow rate instead. When comparing mass flow rates, the actual temperature and pressure need not be the same; however, the standard temperature and pressure (STP) must be equal. In Europe, it is common to instead use "normalized" temperature and pressure conditions (NTP). When using NTP, the mass flow rate will have an "N" instead of an "S" to indicate mass flow (NLPM vs SLPM).

The standard pressure is usually 1 atmosphere, and variance really only comes from using different engineering units and rounding. The standard temperature typically varies between 0 and 25°C with common choices including 0°C, 20°C, 21°C, 70°F, and 25°C.

Effects of STP/NTP

Most mass flow devices are calibrated for a specific STP/NTP. Laminar differential flow technology is unique in that you can change the STP/NTP in the field with no loss in accuracy.

Consider a portable meter used to verify various flow rates at different companies, each with their own STP or NTP. If the standard has an STP of 25°C while the device under test has an NTP of 0°C, what happens?

Standard and normal are simply nomenclature, so using one or the other doesn't actually change anything about the measurement. However, having a lower standard temperature will cause the device under test to appear to have a lower than actual flow rate. This is because volume decreases with temperature. Since temperature in the ideal gas law is given in Kelvin, it would read:

$$\frac{(0+273.15)}{(25+273.15)} = 91.6\% \text{ of the flow rate of a 25°C device.}$$

A device could easily be mislabeled as out of calibration simply by selecting different STP, so it is useful to keep this in mind.