

Gas Laws

I. System in Equilibrium

In thermodynamics a system is said to be in an equilibrium state if its pressure and temperature have a definite value throughout the system.

This means that any changes that are occurring in the system by heating, etc. are happening slowly enough that the atoms or molecules at an interface where energy is exchanged have time to bang into many other atoms and molecules and distribute the energy throughout the system so that the pressure and temperature are the same everywhere so that it makes sense to talk about the pressure of the system and the temperature of the system.

Everything in this course assumes this special case of equilibrium thermodynamics.

The more general case of non-equilibrium thermodynamics which includes lasers, quantum fluids, etc is almost exclusively the domain of physicists at the present time.

II. Gas Laws

The volume of a gas can change by large amounts unlike a liquid or solid which are said to be incompressible. In the 1600's, 1700's, and 1800's many scientists performed experimental studies on the nature of gases in equilibrium states changing temperature, pressure, and volume for a closed gas container (fixed number of gas particles).

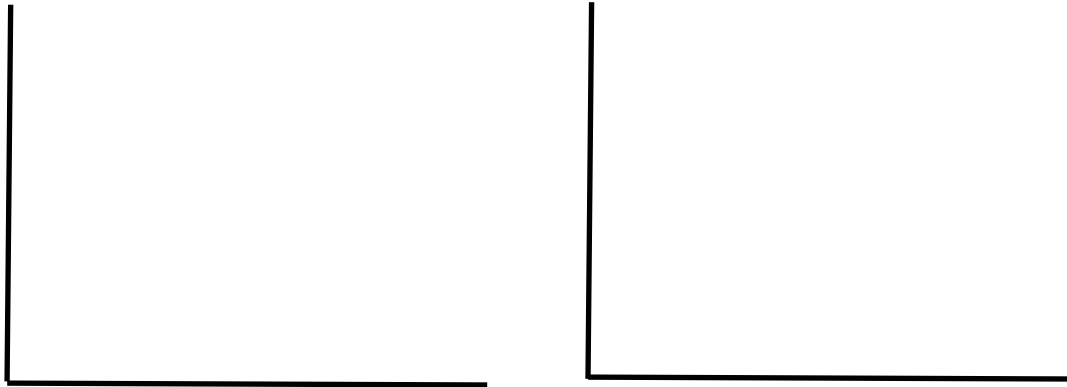
A. Boyle's Law

The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.

The law was initially discovered by Richard Towneley and Henry Power. Robert Boyle confirmed their results and published it in 1662. Robert Hooke who we met previously in the course was Boyle's assistant and built the apparatus used in the experiment.

B. Charles Law

The volume of a given mass of an ideal gas is directly proportional to its temperature on the absolute temperature scale (in Kelvin) if pressure and the amount of gas remain constant; that is, the volume of the gas increases or decreases by the same factor as its temperature.



Jacques Charles found the law in the 1780's. It was independently rediscovered by John Dalton in 1801 and by Joseph Louis Gay-Lussac who published the result in 1802. Charles' interest in gas laws was driven by the Hot Air Balloon craze that swept France.

C. Gay-Lussac Law

The pressure of a gas of fixed mass and fixed volume is directly proportional to the gas' absolute temperature.

Found by Joseph Gay-Lussac in 1809.

D. Avogadro's Law

Avogadro's law states that, "equal volumes of all gases, at the same temperature and pressure, have the same number of molecules".

Amedeo Avogadro hypothesized this law in 1811. It was not widely accepted by chemists for over 40 years.

E. STP (Standard Temperature & Pressure)

STP is when $T = 273 \text{ K}$ & $P = 1 \text{ atm}$.

An important result of Avogadro's law is that 1 mole of any gas occupies 22.4 liters at STP.

F. Ideal Gas Law

Combining all of these experimental results gives us the ideal gas law:

where $k = 1.38 \times 10^{-31} \text{ J/K}$ is the Boltzman constant

Or Equivalently

where $R = 8.31 \text{ J/(mol.*K)}$ is the ideal gas constant.

III. Equation of State

The state of a equilibrium system (such as a gas) is usually defined by just a few parameters. For instance, the state of a gas is defined by just four parameters: 1) Temperature – T ; 2) Volume – V ; 3) Pressure – P ; and 4) Number of Particles – N . These parameters are not independent of each other as they are related by the interaction forces between the atoms or molecules that make up the system. An equation of state is an equation which gives this relationship between one of the parameters and the others.

One of the most famous equations of state is the Ideal Gas Law.