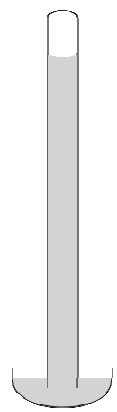
Gases and the Atmosphere

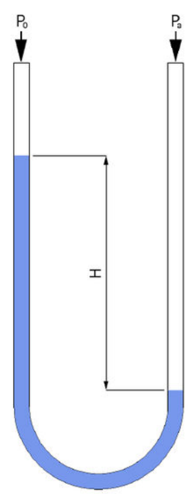
Pressure

- Force per unit area
  - Atmospheres (atm), Pascals (Pa), mm of Mercury (mmHg), millibar (mb)
- A manometer is used to measure pressure
  - Usually called a barometer when used to measure atmospheric (or barometric) pressure

- A column of mercury (the oldest type of manometer)
  - Invented by Evangelista Torricelli in 1643



- U-tube manometer
  - Invented by Christian Huygens in 1661



Converting

- 1 atm = 101.3 kPa
- 1 atm = 760 mmHg
- 1 kPa = 10 mb

Temperature

- Temperature is a measurement of how hot or cold a substance is based on an arbitrary scale
  - Fahrenheit, Celsius, Kelvin

Kelvin Temperature Scale

- Based on the theory of absolute zero
  - The lowest temperature that can be achieved
  - Lord Kelvin reasoned that at this temperature all molecular motion would stop (kinetic energy would be zero
- Symbol, K
  - We do not say degrees kelvin, just kelvin
- Conversion from Celcius temperature

$$K = {}^{\circ}C + 273$$

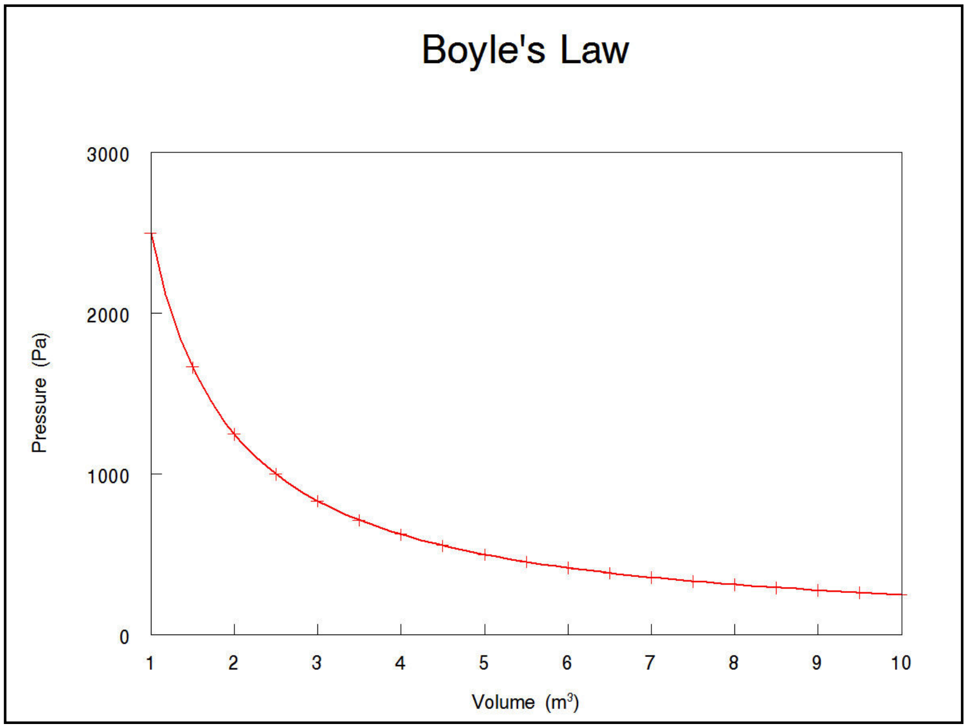
Gas Laws

Robert Boyle (1600)

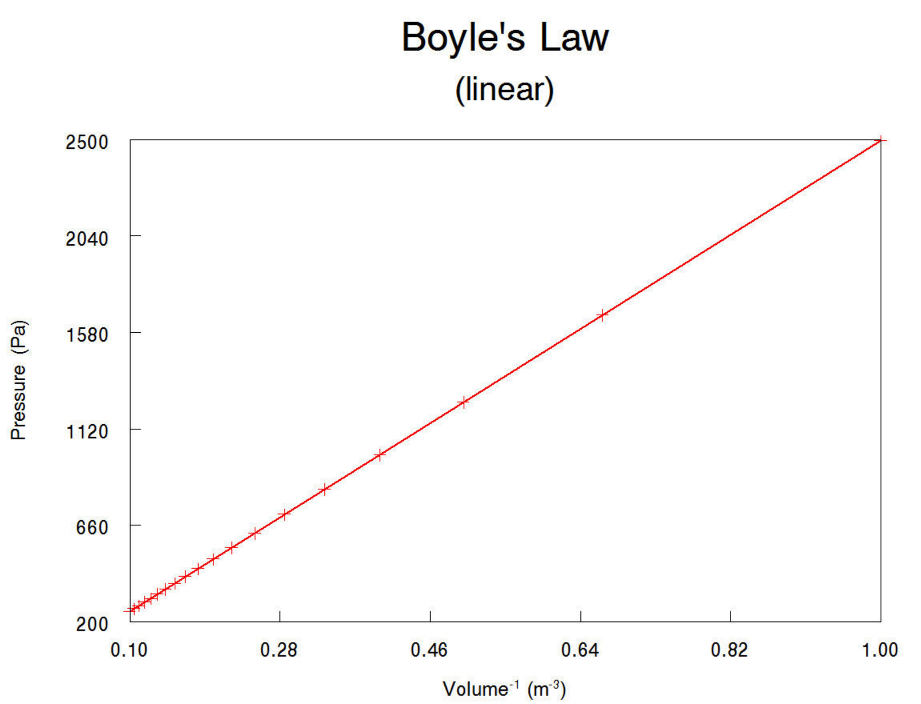
- Boyle's Law
  - at a constant temperature, the volume of a given mass of gas varies inversely with pressure

$$P \propto \frac{1}{V}$$

$$P_1V_1 = P_2V_2$$



- Graphing Pressure vs $Volume^{-1}$ confirms the inverse relationship between pressure and volume



Example

- If 3 L of gas is initially at a pressure of 1 atm, what would be the new pressure to cause the volume of the gas become 0.5 L?

$$P_1V_1 = P_2V_2$$

$$(1\text{ atm})(3\text{ L}) = P_2(0.5\text{ L})$$

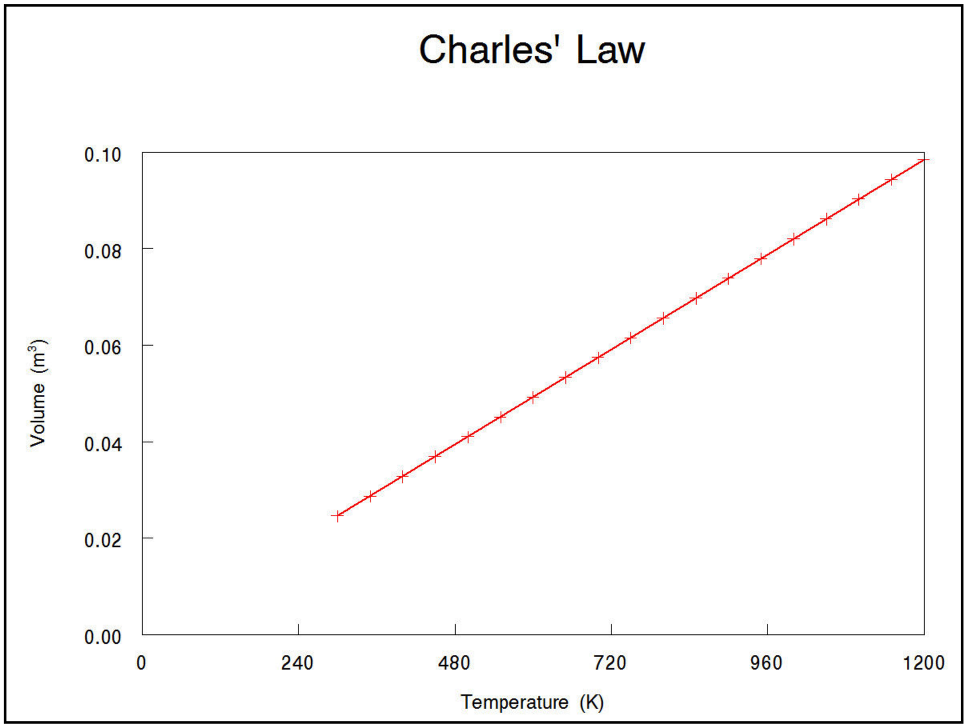
$$P_2 = 6\text{ atm}$$

Jacques Charles (1790)

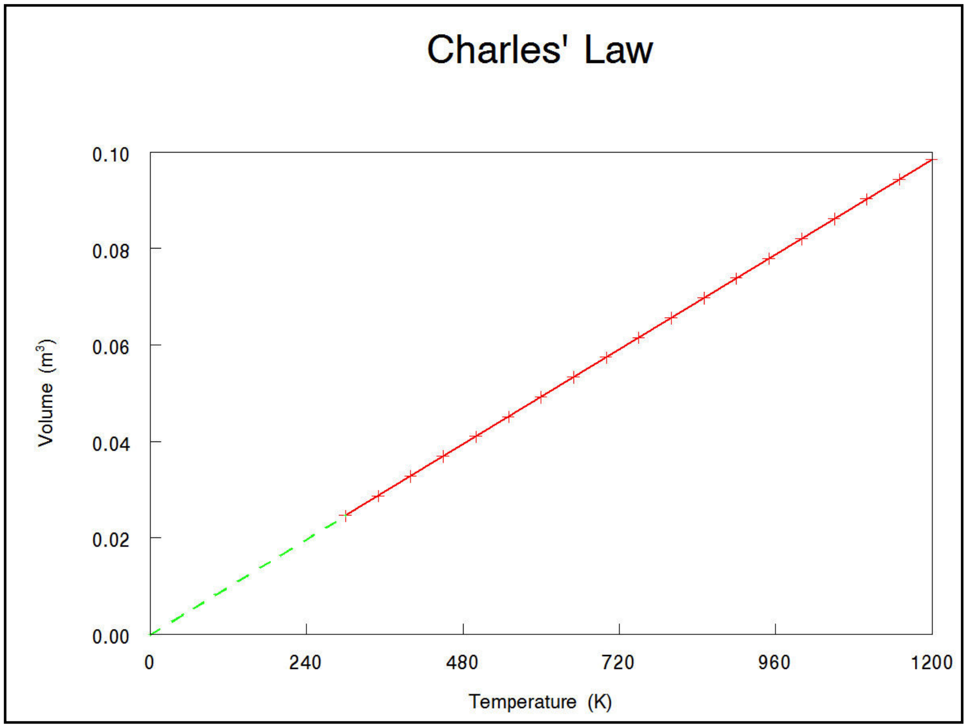
- Charles' Law
  - at a constant pressure, the volume of a given mass of gas is directly proportional to its (absolute) temperature

$$V \propto T$$

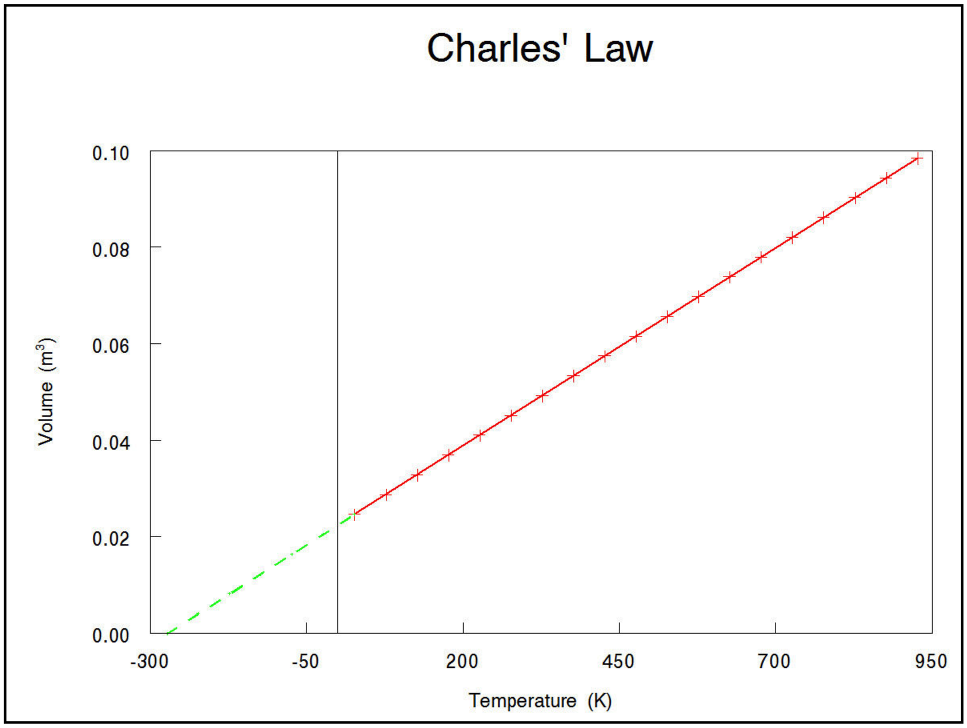
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



- If we extend the line to the horizontal axis, we see that it intercepts at T=0 K
  - The lowest possible temperature is absolute zero
  - Charles' Law therefore confirms the idea of absolute zero



- If we use Celsius temperature instead of Kelvin, we can see that the value of absolute zero is -273 ^{o}C



Example

- The temperature of 6.00 L of a gas at 25°C is increased to 227°C. Determine the volume at the new temperature.

$$25.0\ ^{o}\mathrm{C} + 273 = 298\ \mathrm{K} \qquad 227\ ^{o}\mathrm{C} + 273 = 500\ \mathrm{K}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{(6.00\ \mathrm{L})}{(298\ \mathrm{K})} = \frac{V_2}{(500\ \mathrm{K})}$$

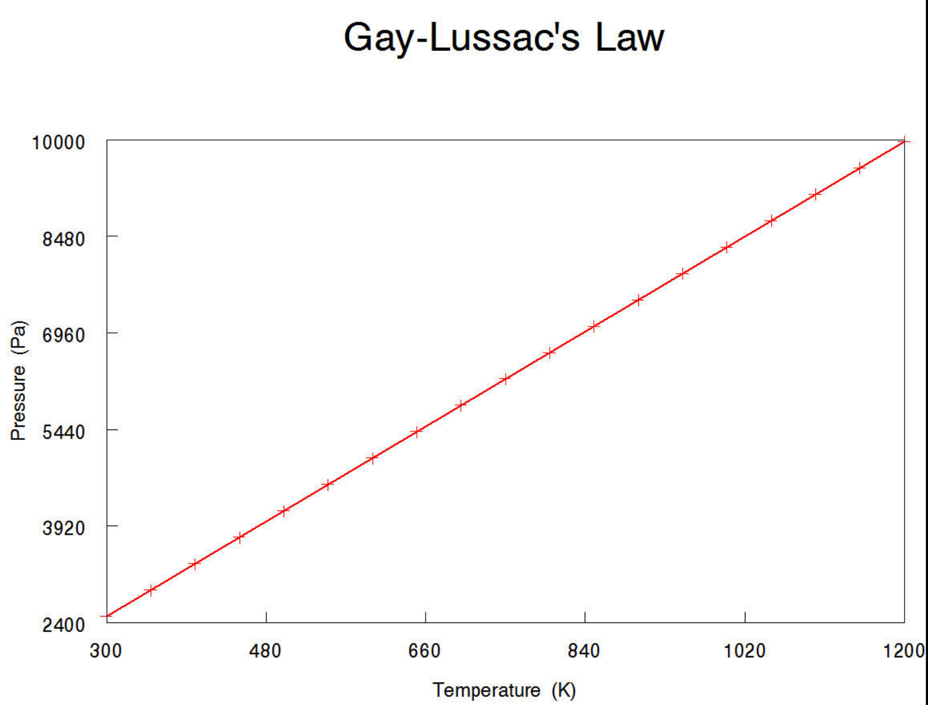
$$V_2 = 10.1\ \mathrm{L}$$

Joseph Louis Gay-Lussac

- Gay-Lussac's Law
  - At constant volume, the pressure is directly proportional to the kelvin temperature

$$P \propto T$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$



Example

- A sample of gas is found to have a pressure of 101.3 kPa at 273 K. Calculate the new pressure at 401 K, if the volume is constant.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{(101.3\ \text{kPa})}{(273\ \text{K})} = \frac{P_2}{(401\ \text{K})}$$

$$P_2 = 149\ \text{kPa}$$

Combined Gas Law

- If we combine the observations of Boyle, Charles, and Gay-Lussac, we get a relationship that we call the combined gas law

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Example

- Salvage divers often use lift bags to lift objects to the surface. Divers are required to make a pre-dive calculation of the forces involved, to ensure the safety of the divers during the recovery. A lift bag contains 145 L of air at the bottom of a lake, at a temperature of 5.20°C and a pressure of 6 atm. As the bag is released, it ascends to the surface, where the pressure is 1 atm and 16.0°C. Calculate what volume the gas would occupy at the surface of the lake.

$5.20\ {}^{\circ}\mathrm{C} + 273 = 278.2\ \mathrm{K}$ $\qquad$ $16.0\ {}^{\circ}\mathrm{C} + 273 = 289\ \mathrm{K}$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(6.00\ \mathrm{atm})(145\ \mathrm{L})}{(278.2\ \mathrm{K})} = \frac{(1.00\ \mathrm{atm})V_2}{(289\ \mathrm{K})}$$

$$V_2 = 904\ \mathrm{L}$$