

GAS LAWS: BOYLE'S LAW

APRIL 7, 2024

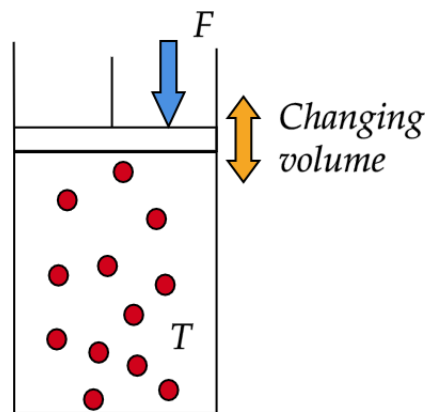
THEORY RECAP

A gas is characterized by its temperature T , volume V and pressure p . Temperature is the measure of internal kinetic energy of atoms or molecules comprising the gas. Volume is the measure of how much space does the gas take up. Pressure is the measure of force exerted by the gas on the walls of the container.

These three quantities are not independent. Our today's class is going to be about relations between these quantities.

What are we actually going to study? Consider a container with a variable volume. The easiest way to achieve it is to attach a piston, like in a syringe but airtight so no gas could escape. Then by moving the piston back and forth we could change the volume of the gas. Pressure of the gas is trying to push the piston upwards, and in order to compensate for it we have to push downwards. If pressure of gas is p and area of the piston is A , the force with which we have to push is

$$F = pA.$$



By changing this force we would change the pressure of the gas - the system will only come to equilibrium when forces acting on the piston are balanced. Finally, we could heat or cool the gas by bringing it to contact with hot or cold objects. We would assume that all gas has the same temperature at every moment of time (neglecting that the part closer to a heat source in reality heats faster). Temperature of the gas can be measured by a thermometer inside the container.

Now we have the tools to explore gas laws. There are three laws and they have similar structure: in each of them one of the basic quantities T, V, p is kept constant and a relation between the other two is studied. Today we will study just one of them with the others to follow.

Boyle's law. First let us keep T constant. We could achieve it by keeping the environment at constant temperature and doing all changes in volume or pressure slowly enough so at every moment the gas is in thermal equilibrium with the environment and its' temperature is constant. This kind of process is called **isothermal**. For example, we can slowly put additional blocks on the piston to change the pressure and look at how volume of the gas changes. This way Boyle's law was discovered:

$$pV = \text{const} \quad \text{for } T = \text{const}$$

which means that at constant temperature pressure and volume are inversely proportional to each other. If pressure is increased, the volume decreases and vice versa. Another way of writing Boyle's law is

$$\frac{p_1}{p_2} = \frac{V_2}{V_1}$$

Here p_1 and V_1 are respectively pressure and volume at some state of the gas and p_2 and V_2 are at some other state with the same temperature.

HOMEWORK

1. A cylinder with a piston is filled with gas. The pressure inside is 1000 Pa. We push the piston inside the cylinder and decrease the volume of the gas two times. Find the new pressure if the temperature of the cylinder is kept constant.
2. A cylinder with a piston is filled with gas at pressure 100 000 Pa. Again, the temperature of the cylinder is kept constant. The pressure inside the cylinder is equal to the pressure outside the cylinder, so the piston does not move. The volume of the gas inside the cylinder is 1000 cm³. We put a 10 kg stone on the piston. The piston moves down and stops, compressing the gas in the cylinder. Find the new volume of the gas if the area of the piston is 10 cm². (To solve this problem you have to remember what the pressure is and how we calculate it).
- *3. In order to make volume of a gas in a cylinder under a piston 3 times smaller one needs to place a block of mass m on the piston. What is mass of another block one needs to add to this one so that volume further becomes 4 times smaller? Temperature is kept constant.