

Phases of matter

We have started discussing states of matter. There are a lot of states of matter, but for the beginning we will talk about 3 of them. These are

1. **Solid** state (a solid object has both definite volume and shape).
2. **Liquid** state (liquids have definite volume – they are almost incompressible but have not a shape).
3. **Gas** state (both volume and shape are determined by the container).

Phase transitions. If some object is a solid, can it be made into a liquid or even into gas? In many cases the answer is yes. Think about water, for instance. Solid water is ice. At 0°C ice melts and becomes liquid water. If we continue increasing its temperature, at 100°C water boils and evaporates which means that it turns into vapor. Now if we go in the opposite direction and lower temperature starting from hot vapor, at 100°C vapor will condense which means it will become a liquid. And at 0°C liquid water freezes to become ice. Here we see that water exists in all three phases: solid (ice), liquid and gas (vapor).

Along the lines we introduced the names of phase transitions: when solid becomes liquid it is called melting. The reverse process when liquid becomes a solid is called freezing. Melting and freezing happen at the same temperature, called the melting temperature. When liquid becomes gas, it is called boiling and the reverse process is condensation. Once again, boiling and condensation happen at the same temperature, called the boiling temperature.

Gases “work hard” for us in our everyday life – for example, hot gas expanding in the cylinder of the engine makes the car move. To design a machine which uses gas to produce work we must know in detail the behavior of gas at different conditions. As we learned, gas consists of huge number of microscopic particles called molecules or atoms (depending on the kind of the gas). It is not possible to track down or describe the motion of each molecule in a gas volume. Fortunately, we do not have to do that. We just must know three important parameters and the way how they depend on each other. The parameters are:

- Pressure
- Volume
- Temperature

We are going to discuss pressure first.

Pressure

Pressure shows how force is distributed over some area. If force F is applied perpendicularly to area A , the pressure is: $P = F/A$

Units of pressure are N/m^2 and have a special name: Pascals, or Pa. This unit is called after a famous French mathematician, physicist and philosopher Blaise Pascal.

For **example**, let's calculate the pressure a person exerts on the floor when standing on two feet. Let us say for simplicity that each of the feet is a rectangle with sides $30 \text{ cm} \times 10 \text{ cm}$ and mass of the person is 60 kg . Then pressure is

$$p = \frac{F}{A} = \frac{mg}{A} = \frac{60 \cdot 10 \text{ N}}{2 \cdot 10 \cdot 30 \text{ cm}^2} = \frac{600 \text{ N}}{0.06 \text{ m}^2} = 10000 \text{ Pa} = 10 \text{ kPa}$$

Normally we do not care too much about this pressure. However, if we try to walk on snow, it becomes important: if the pressure is too big, our feet will fall through the snow. In order to reduce pressure and prevent falling through the snow one could make the area of contact bigger by wearing snowshoes or skis.

Gas always applies pressure to the walls of the cylinder or any other vessel. The pressure can be low as in a balloon or high as in a barrel of a gun during the shot. Our atmosphere also produces pressure. It is $\sim 100 \text{ kPa}$ ($101,300 \text{ Pa}$ to be exact) at sea level.

Homework:

- 1) The closed bottle is half full of mercury. Is there any mercury in the other half of the bottle?
- 2) What pressure do you produce when pushing a pushpin into a wall with a force 5 N ? Take the area of a pushpin to be 0.01 mm^2 . Express the answer in Pascals using scientific notation.
- 3) Calculate total force applied by the atmosphere to a square surface $30 \text{ cm} \times 30 \text{ cm}$.
- 4) What happens to the air pressure inside the balloon if we squeeze the balloon? Why?