Brownian motion of smoke particles

Aims of the experiment

- Observe the motion of minute particles in air.
- Interpret the random motion as Brownian molecular motion.
- Observe the temperature dependence of the particles.
- Become familiar with a microscope.

Mixtures comprising a gas or mix of gases and finely distributed particles are referred to as aerosols. Aerosols can be differentiated based on the physical state of their particles. If these involve solid particles that are suspended in the aerosol, the phenomenon is commonly referred to as smoke. However, if the aerosol contains suspended matter in liquid form it is also called mist.

A particle that is suspended in a gas undergoes motion that alternates continuously in respect to speed and direction. J. Perrin provided an explanation for this molecular motion discovered by R. Brown, which is caused by the gas molecules colliding with the particles. The motion is therefore more intense the smaller the particle. It comprises a translational motion and an alternating rotation at the same time.

The mean quadratic displacement σ^2 of a particle per unit of time was confirmed by A. Einstein and M. Smoluchowski.

$$\sigma^2 = \frac{RT}{N_A 3r\pi\eta}$$

Here *R* describes the universal gas constant, *T* the temperature and N_A the Avogadro constant. The radius *r* of a Brownian particle and the viscosity η of the gas are also responsible for the displacement of a particle.

The smaller the particles, the greater and hence more visible the motion of the particles is. A temperature increase also results in more intense motion. This insight helped Perrin to determine the Boltzmann constant k_B experimentally, for which he received the Nobel Prize.

$$k_B = \frac{R}{N_A}$$

The motion of smoke particles in air is observed in this experiment. To do this, a smoke chamber is filled with smoke and the smoke observed under a microscope. For better visibility of the smoke particles, light is also shone into the chamber from the side.

Fig. 1: Set-up for observing Brownian motion of smoke particles in air.

Sel-2015-02

Risk assessment

There are no associated hazards.

Equipment and chemicals

1 Smoke chamber.....372 51
1 Microscope EduLED, mono 2 .....MIK738865
1 Transformer, 6 V AC,12 V AC/ 30 VA.....521 210
1 Lamp housing with cable 450 60
1 Lamp, 6 V/30 W 450 511
1 Aspherical condenser 460 20
1 Stand base, V-shaped, small 300 02
1 Disposable syringe 10 ml, from set of 5 .....665 958ET5
1 BMS ECOCAM 8, gosseneck camera 8……..MIK74704
1 Microscope adapter for BMS EcoCam 5 a.8...MIK747039
Also required:
Incense cone or cigarette
PC or end device for image transmission

Set-up and preparation of the experiment

1. Set up the experiment as shown in Fig. 1. Turn the lens 10 x into the light path of the microscope EduLED, mono 2 for this. This sets the magnification to 100 x.
2. If you wish to transfer the image, install the camera on the microscope, connect to the end device and switch on.
3. Place the smoke chamber on the microscope stage and focus with the coarse focussing of the microscope so that the centre of the smoke chamber is shown in focus. (Note: If you first focus on a sheet of paper with writing on it, this will make it easier to find the plane.)
4. Fasten the lamp housing on the stand base, install the lamp and equip with the aspherical condenser.
5. Connect the cable from the lamp to the 6-V output of the transformer. Switch on the transformer and position the lamp so that the focus of the illumination is incident in the centre of the smoke chamber. (Note: A paper can be held out instead of the smoke chamber as a check.

Performing the experiment

1. Light an incense cone or cigarette, allow to burn for a short time and then blow out. Collect the rising smoke with the syringe.
2. Inject the smoke into the smoke chamber and then close the ends of the hose with the plastic caps.

Note: The motion of the smoke particles remains observable for longer if you make the hoses much shorter and close the ends with caps.

2. If necessary, twist the smoke chamber slightly to reduce the brightness in the smoke chamber.
3. Focus the microscope and observe the motion of the particles.
4. If the camera is installed, transfer the image to the projector or screen.

Observation

The illuminated smoke particles are visible as small white dots making random wobbling and zigzag movements (compare Fig. 2). White dots disappear from the the plane focussed with the microscope or appear in it.

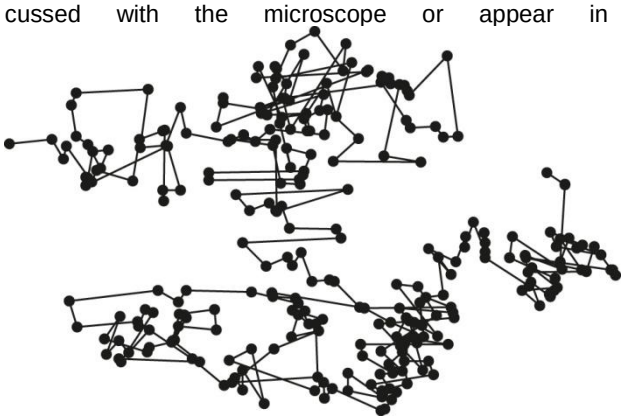

Fig. 2: Schematic representation of the Brownian motion of smoke particles in air.

Evaluation of the results

The movements of the smoke particles result from their collision with the air molecules in thermal motion.

The smoke chamber can also be heated. Here it can be observed that the percentage of particles with more movement increases if the temperature is raised.

The insights gained in regard to Brownian molecular motion can now be applied for the interpretation of everyday phenomena (e.g. boiling of a liquid, diffusion).

Cleaning and disposal

No special cleaning or disposal necessary.