Physics. — "*The Brownian Movement of a Thread*". By A. HOUDIJK and Prof. P. ZEEMAN.

(Communicated at the meeting of November 29, 1925).

In an address on "Experimentell nachweisbare, der üblichen Thermodynamik widersprechende Molekularphänomene" delivered at the 84. Versammlung deutscher Naturforscher und Aerzte in 1912 [1]) VON SMOLUCHOWSKI treats many phenomena that have been known for a long time (Brownian movement, opalescence of gases in the critical state, oscillation of the gas density about a normal middle value) seen from one point of view.

According to the kinetic theory the condition of an isolated system oscillates about a normal state, and can even very far depart from it under definite circumstances, in consequence of which the phenomena in question ensue.

The conditions through which a system in equilibrium passes, correspond to a canonical distribution, and the chance to a definite system defined by the coordinates p and the moments q is:

$$dW = ae^{-\frac{N}{RT}E}\, dq_1\, dq_2 \ldots dp_1\, dp_2 \ldots dp_n$$

in which E is the total energy.

On integration with respect to all the variables except ε (identical with a q) which determines the deviation of the system, the number of systems at a definite moment with an ε lying between ε and $\varepsilon + d\varepsilon$, is:

$$dW = ce^{-\frac{N}{RT}\chi(\varepsilon)}\, d\varepsilon \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This well-known equation — BOLTZMANN's exponential law — is characteristic of the kinetic theory. It indicates how far in consequence of the unordered thermal movement a parameter of a system departs from the value corresponding to stable equilibrium.

VON SMOLUCHOWSKI gives several applications, and treats two of them referring to the deformation of a solid body, which differ, therefore, from the known phenomena of variation of the parameter through the molecular motion.

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[1]) M. v. SMOLUCHOWSKI, Phys. Zeitschr. 13, 1912 (1069).

One of them, the subject of our experimental investigation [1]) is the displacement of the lower end of a thin thread hanging vertically.

Any departure from the state of equilibrium will have the same probability. The factor a in formula (1) is, therefore, constant. Besides — since we are concerned with gravity and with elastic forces — the work done on a displacement from the state of equilibrium, is a quadratic function of the coordinates, so that we, therefore, get a distribution of deviations according to GAUSS's law of errors.

The strict calculation of the case is complicated, for the very reason that besides the work of gravity, also the work required for the bending should be considered.

The order of magnitude of the mean deviation is, however, also obtained when the thread is conceived as a rod, and only gravity is taken into account.

The mean displacement of the end of the thread becomes:

$$\sqrt{\overline{\delta^2}} = \sqrt{\frac{RT}{N} \frac{2}{\pi a^2 \varrho g}}$$

in which a is the radius of the cross-section of the thread, and ϱ the density of the substance used.

This formula may also be derived by another way.

The difficulties met with in the experimental investigation, are among others radiometric phenomena and vibrations of the ground.

In main lines the arrangement was as follows.

The thread attached at one end, was placed in a small tray covered at the front and at the backside by a cover-glass. The free end of the thread was projected on the slit of a falling plate outfit, as is used among others to record electro-cardiograms. A PHILIPS Tungsten arc-lamp with an object glass as condenser serves for the illumination; for the projection is used a microscope with horizontal tube, provided with an apochromatic object glass and a compensation-eyepiece. The whole apparatus stands on a free-stone plate, attached to three free-stone pillars which are mounted on one of the heavy concrete floors of the physical laboratory "Physica". These floors weigh ± 250.000 kg., and rest — clear of the building — on a great number of poles driven in deep. Moreover, the observations were made in the night, between 1.30 and 3.30 a. m., after it had been ascertained that the movement of the floor has a large period only then. With a diaphragm the smallest quantity of light possible for the projection was transmitted.

For a long time observations were also made in the hall of the country-

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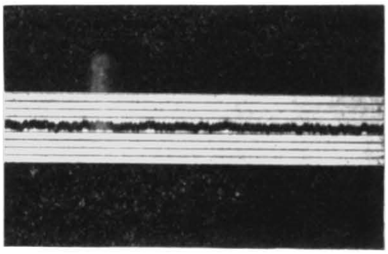
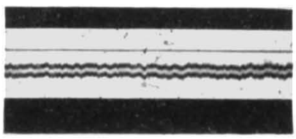
[1]) This investigation, in progress for a long time already, is mentioned in:
A. EINSTEIN. Untersuchungen über die Theorie der "Brownsche Bewegung". OSTWALD's Klassiker N⁰. 199. Anmerkung 15. 1922.
M. V. SMOLUCHOWSKI. Abhandlungen über die Brownsche Bewegung und verwandte Erscheinungen. OSTWALD's Klassiker N⁰. 207. Anmerkung 30. 1923.

house of one of us at Huis-ter-Heide, and a few times in the cellar of a house at Zeist. In a nightly observation at Huis-ter-Heide, made by one of us, the deviations of the end of the thread were directly observed, and the magnitude estimated by the eye piece micrometer. Many observations were made in the older physical laboratory, where the apparatus was mounted on a much smaller block of concrete.



Platinum 1 μ.



quartz 2 μ.

Wherever the investigation was performed, it was always found that the aspect of the phenomenon was the same.

The subjoined pictures give an idea of the photographs obtained.

The measurments were made with the microphotometer, and visually by enlarging the image.

The results, both of the last-mentioned measurement and those of the above-mentioned direct estimation, are in good agreement with the formula derived above.

The investigation was made with threads of different materials and different cross-sections.

Further details and results will be given in the thesis for the doctorate of A. HOUDIJK, to be published later.

In the experiments the photographs are, of course, obtained with the thread vertical.