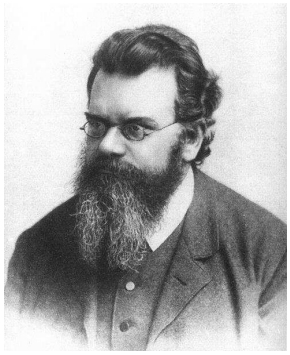
Biography: Ludwig Eduard Boltzmann (1844-1906)



Ludwig Boltzmann became famous in many fields of science. However, the real fame brought him the study of system of particles, for which drew up his famous laws: the law of the canonical distribution of energy, so called Boltzmann law (used in physics and chemistry - as far as the equation defining how many subsystems of specific energies is in the thermal equilibrium of the system), the statistical explanation of the nature and the so called entropy and the Stefan-Boltzmann law (which allows you to calculate the total energy flux emitted by a blackbody at a given temperature). His original saying was: "*There is nothing more practical than a good theory.*" Despite the groundbreaking works outside the scope of contemporary research, he was not understood by many great scholars, for example, Wilhelm Ostwald and Ernst Mach, what contributed to his untimely death.

Ludwig Boltzmann was born on February 20, 1844 in Erdberg, a suburb of Vienna, which was the capital of the Austrian Empire. Ludwig's father, was a tax clerk, his mother was Katharina Pauernfeind of Salzburg. The boy initially taught at home, enjoyed trips to the countryside to collect butterflies and beetles. Ludwig Boltzmann also liked to tinker. He studied at the Gymnasium in Linz, where he showed great interest in mathematics and science. Long hours poring over books in low light of the candle very weakened his sight, which gave him a misery, especially in adulthood. He received piano lessons and it was from the Anton Bruckner. For the rest of his life he liked to play the instrument, alone or in duet with his son Arthur, who played the violin. Ludwig Boltzmann at age 15 lost his father.

Studies in physics Ludwig Boltzmann began in 1863 at the University of Vienna. He was a student of Josef Loschmidt, Josef Stefan, Andreas von Ettingshausen and Jozsef Petzval. He completed his doctorate in 1866 and a year later he delivered his first lecture. At age 25 was named professor of mathematical physics at the University of Graz in the province of Styria. The study period dates his interest in electromagnetism, mechanics and thermodynamics. He explored the electromagnetic theory of Maxwell. From the very beginning of his career, Boltzmann was highly esteemed by his older colleagues. Around 1870, at the University of Berlin has worked with Robert Bunsen, Gustav Kirchhoff and Hermann von Helmholtz. In the years 1873-1876 he taught at the University of Vienna, later became professor of experimental physics at the University of Graz.

On July 17, 1876 Ludwig Boltzmann married Henrietta von Aigentler, attractive blue-eyed woman with long, curly blond hair. Henrietta often called Ludwig "sweet fatty", because he was a huge fondness for Viennese cuisine and beer. Ludwig even used to joke that after drinking the beer loses its brilliant ability to remember numbers, because he never remembered how much he drank. Ludwig and Henrietta had five children, two sons, Ludwig Egon and Arthur and three daughters, Henrietta, Ida and born in Vienna, Elsa. Boltzmann spent with her wife 14 happy years in Graz and during that time developed the ideas of the statistical concept of nature. For this he was honored by the government and the academic community. In 1878 became the dean of the Faculty of Physics, in 1885 he became a member of the Imperial Academy of Sciences.

In 1890, Ludwig Boltzmann accepted the chair of theoretical physics at the University of Munich. After the death of his professor Josef Stefan (1835-1893) in 1894, Boltzmann was appointed chair of physics at the University of Vienna. It was a difficult period in the life of Ludwig, in particular, he could not create a good group of friends and colleagues such as it was in Munich. An additional difficulty was the appointment of Enrnest Mach (1838-1916), an ardent opponent of Ludwig, in 1895 as a professor of philosophy and history of science. Ernst Mach was a great experimenter, a historian of physics, opponent of atomism and positivist philosopher. Therefore, the Ludwig Boltzmann accepted the nomination for the professor of theoretical physics in Leipzig. After the retirement of Mach and due to poor health, Boltzmann returned to Vienna in 1902. After his return to Vienna he was appointed in place of Mach.

Boltzmann's lectures on philosophy of nature has always enjoyed a great popularity. His first lecture was a huge success. The largest available hall was filled to the brim (completely). The success of the lectures of Boltzmann was so huge that the local newspapers described the whole event. The Emperor Franz Joseph congratulated Boltzmann's success and told him that he is pleased with his return to Vienna. But, Gerald Holton wrote: "*the careful preparation of lectures, a great sense of humor and kindness made that the lecture hall was full of students and guests.*"

Boltzmann enriched kinetic theory by several extremely important results. In the nineteenth century physicists have begun studying a new field of physics, called thermodynamics. Thermodynamics is the study of thermal phenomena and processes associated with them. In the process of transformation of heat into motion heat energy turns into kinetic energy, of course, while keeping the total energy constant. Then was formulated the second law of thermodynamics, which requires that every system tends to a state of greatest disorder. The direction of energy flow is only one and is such as to ensure the state of thermodynamic equilibrium. The first formulation of the second law of thermodynamics gave French physicist Nicolas Carnot (1796-1832), then in 1850 it was developed by Rudolf Clausius (1822-1888), who introduced the concept of entropy. Impressed by the works of Maxwell, Boltzmann set himself the task of the statistical formulation of the second law of thermodynamics. In 1872 he announced a 126-page dissertation on: "*Further studies of the thermal equilibrium of*

gas particles" containing the famous H function, describing the evolution of the system in time. Using function H, Boltzmann gave statistical evidence on the growth of an isolated system entropy (second law of thermodynamics).

In 1860, James Maxwell gave the kinetic theory of gases. His work showed that the macroscopic properties of gases are determined by the behavior of gas particles. Collisions between particles were treated according to Newtonian mechanics. Maxwell in his theory failed to explain the trend of gas to the state of thermodynamic equilibrium.

In 1866 Boltzmann made the first attempt to clarify the thermodynamic equilibrium. In his first paper, in 1868, twenty-four Austrian physicist expanded the description of the energy distribution of particles and the case of the presence of external field (Boltzmann distribution). Statistical law of canonical distribution of energy describes the average number of subsystems in a state with energy E in the system, which is not exchanging matter with the environment (is closed), but that could heat exchange (not insulated) and remaining in thermal equilibrium with the environment:

$$N(E) = Ae^{-\frac{E}{kT}} \qquad (1)$$

where: N (E) - the average number of subsystems in a state with energy E, A - constant of proportionality, k- Boltzmann constant, T - absolute temperature of the environment.

The Boltzmann distribution law (1) shows that the number of subsystems in the state with energy E decreases with increasing energy E, and increases with increasing temperature T.

It seemed initially, that the Boltzmann equation leads to a paradox - where gas molecules spread out in accordance with Newton's mechanics, the process should be reversible. But it is clear that the gas released from the cylinder can not be back to catch. In 1877 Boltzmann responded to these concerns, giving a statistical definition of entropy in a formula, now called the Boltzmann formula. He realized that introduced by Clausius entropy, a rather mysterious quantity, is a measure of disorder in the system. The increase of entropy corresponds to an increase of disorder. A formula developed by Boltzmann associated the macroscopic parameter -entropy S with the microscopic parameter - he thermodynamic probability W of the state. Boltzmann's formula was written by Maxwell in the following form:

$$S = k \log W , \qquad (2)$$

where k is one of the most important physical constants, called by the Planck - Boltzmann constant.

Commonly known Boltzmann equation describes the tendency of each gas to pass, as time passes, the state of equilibrium. This is the most important and most concise formulation of the law of entropy. By formula (2) derived by Boltzmann we can explain the second law of thermodynamics, saying that the entropy of the universe always increases. It gives highlighted direction to the passage of time: past - less entropy, the future - the greater entropy (the so-called arrow of time). In addition, formula (2) is one of the most beautiful theorems of physics.

In addition to works on the kinetic theory of gases Boltzmann published the works in the field of mathematics, chemistry, physics and philosophy. In 1884 he formulated the theoretical law of radiation of bodies with a given temperature (the Stefan-Boltzmann law) in the form:

$$\phi = \sigma T^4 \qquad (3)$$

Despite poor eyesight Boltzmann was a good experimentalist. He attached a great importance to the experiments and was an opponent of German idealists like Schopenhauer and Hegel. Ludwig Boltzmann was an ardent supporter of Charles Darwin (1809-1882). Ludwig agreed with the atomistic theory of matter, but also acknowledged the possible existence of even smaller particles. Boltzmann in his works, wrote that "we are ready to reject the constancy of the atom in cases where other assumption can better explain the phenomenon." Kinetic-molecular theory of matter has been very strongly criticized by representatives of the so-called "energetism". At the head of that group steel Wilhelm Ostwald and Ernst Mach. They proclaim that physics should deal only with quantities, that can be determined from measurements, and not consider the microscopic imaginary objects. Disputes were sometimes very fierce, and certainly related to the meaning of all Boltzmann's studies.

Boltzmann did not enjoy good health. He suffered from various ailments - asthma, migraines, almost entirely lost his sight. In the summer of 1906 visited Trieste. Disputes with representatives of "energetism" were very exhausting and they led to his nervous disorder. A strong depression on September 5, 1906, when his wife and daughter swam in the bay, Ludwig Boltzmann hanged himself. The irony of fate that it happened when the enemy began to give way to atomism in the face of a growing number of facts proving the existence of atoms and molecules. He was buried at the Central Cemetery in Vienna, and on the marble tombstone is carved his bust and the equation (2).

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