and in the "fire-like" group are placed flame, light, heat, and combustible fumes. All bodies consist supposedly of one primary matter and are constructed of invisible particles ($\sigma\tilde{\omega}\mu\alpha\tau\alpha$). Each group of bodies is characterized by the shape of its particles. Plato considered the shape of regular polyhedrons as "most plausible." He ascribed a cube shape to particles of the first group, an icosahedron shape to particles of the second group, an octahedron shape to particles of the third group, and a tetrahedron shape to particles of the fourth group. According to Plato, groups 2, 3, and 4 can be transformed into each other because the facets of an icosahedron, an octahedron and a tetrahedron are equilateral triangles. When they collapse into separate triangular plates (facets) the hollow polyhedrons are reconstructed and change into each other. The "earth-like" cubes (of the first group) are deprived of this possibility. Plato considered polyhedrons and triangles as ponderable particles. He even asserted that they are fastened to each other with "numerous miniature brads."* Each of the four groups embraces an enormous number of substances which are distinct from one another only by the dimensions of their invisible polyhedrons.

Plato described in detail the process of mutual transformation of the various kinds of matter. Penetration of the "sharp" particles of fire into the "water-like" solid phase causes melting. Fiery tetrahedrons break the icosahedrons of the melt into plates and causes them to restructure themselves as "air-like" octahedrons of vapor. The removal of particles of "fire" leads to a congealing and precipitation of the solid phase from the melt. Conservation of the original number of triangular plates is rigorously observed in all these processes of particle restructuring. Plato expressed this in the form of original balance equations of this type:

1 "water" $\rightarrow$ 2 "air" + 1 "fire"

(i.e., 20 triangles of water are transformed into 2×8 triangles of air + 4 triangles of fire). Besides this rule governing the quantitative side of such processes, Plato formulated phase-equilibrium laws that determine the directions of the processes (up to this time, historians have not paid attention to this). So, the first phase-equilibrium law asserts that identical particles do not destroy each other because a homogeneous system is always in a stable equilibrium and rest. The second law states that in the presence of several phases (for example, a mixture of "fire-like" and "water-like" particles) there arise movements, i.e. a battle between them, during which the phase that is less stable and is less concentrated is subjected to destruction; its particles are restructured and take the structure of the predominant phase. Finally, the third phase-equilibrium laws deals with the mixture of two phases that are approximately identical in stability and concentration. The battle between them leads to a dissociation of the particles that continues until either the particles of one of the phases gather together and are precipitated or the particles of this phase are restructured into a homogeneous mass similar to the other phase and are dissolved in it. In the light of these laws Plato examined not only the "mixture" of fire and liquids, but also the solutions of solid salts in water. Thus we find here a comprehensive system of molecular physics without a parallel in the science of antiquity. Plato's physics was not understood by the ancient natural philosphers (e.g., Aristotle), but it turned out to have had an influence on physicists and chemists from the 16th to the 18th centuries.

*For this reason, Heisenberg's treatment of these triangles as mathematical abstractions [6] is mistaken.

[1] F. Rosenberger, History of Physics, Transl. ed. by I. Sechenov, Part 1, M.-L., 1933.

[2] E. Hoppe, Handbuch der Physik, Band 1, Kap. 1. Geschichte der Physik, Berlin, 1926, pp. 8–9.

[3] Platon, Oeuvres complètes, tome X, "Timaée", texte établi et traduit par Albert Rivaud, Paris, 1925.

[4] Eva Sachs, Die fünf platonischen Körper (Philologische Untersuchungen 24), 1917.

[5] Ch. Mugler, La physique de Platon, Paris, 1960.

[6] W. Heisenberg, Physics and philosophy, N. Y., 1958, p. 69.

I. D. Rozhanskiĭ, On the Question of the Rise of Atomic Theory in Antiquity

The problem of the rise of ancient atomic theory is among the most puzzling problems in the history of science. From what we know about the atomic theory of Leucippus and Democritus it follows that it was a systematic and well-developed doctrine. Were there precursors of it in Greece or in other countries? If not, then what was the nature of the stimuli that prompted the early Greek thinkers to come to the idea of the atom as the smallest structural unit of matter? The well-known Aristotelian explanation deriving the atomic theory from the teaching of the Eleatics is from this point of view insufficient. In order to understand how the idea of the atom could be conceived in this epoch when both physics and scientific methods of research were non-existent, it is useful to examine several characteristics of prescientific thought in general. One of these characteristics was the operation of pairs of opposite concepts, such as light and dark, right and left, even and odd, and others, to which special, occasionally magical meaning was ascribed. A specific feature of Greek psychology was that the most important of the pairs like this was the pair limited—limitless. This was precisely the pair that was in first place in the system of Pythagorean opposites which, according to the words of Aristotle, played a primary role among the Pythagoreans. The idea of the limited for the Greeks of this epoch was equivalent to ideas of order, shape and harmony; the opposite idea of the limitless expressed disorder, formlessness, and disorganization. Translated into a cosmic scheme of things the pair limited–limitless turned out to be related to another pair that was also exceptionally characteristic for Greek thought, namely the pair cosmos—chaos.

The beginning of the 5th Century B.C. in Greek science was characterized by formulation of a whole series of concepts which in the preceding epoch either still did not exist or were still being only vaguely outlined. In particular, it was precisely at this time that there arose a sharp awareness of the idea of spatial infinity.

Leucippus supplemented this idea with the idea of a plurality of worlds, an idea which was alien to Greek thinking in cosmology prior to this time. Also at this time was conceived the idea of an inner structure of things, defined by primary structural units from which the world was built. Right in this spirit Empedocles rearranged the ancient notions about four primordial elements. Leucippus approached this problem in a manner differing from that of Empidocles. He transferred the opposition of limited—limitless, which was basic for Greek thought, from the cosmic scheme to the microscopic scheme. In this process, the opposition of cosmos to chaos became an opposition of the smallest material particles—atoms—to empty space. Indivisible, impenetrable, always invariant atoms express in the final analysis the Greek idea of the limited; with this is connected the fact that it is the form that is the basic and essentially singular positive attribute of atoms. Conversely, the idea of the limitless turns out to be naturally conceived empty space without boundaries and without inner divisions. It is clear from Aristotelian texts concerning atomic theory that this was precisely the situation; they are all shot through with the idea of dualism of the full and the empty, the existent and the non-existent, atoms and empty space.

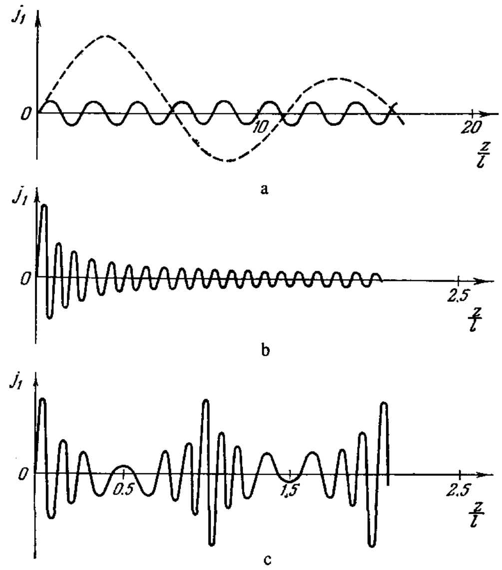
The above-mentioned peculiarities of the concepts of the early atomic theory still do not characterize it fully. Another aspect of the atomistic hypothesis is the eternal motion of atoms "leaving traces of themselves in all directions." This aspect cannot be explained on the basis of only speculations with the ideas of the limited and the limitless; it is necessary here to seek a parallel or a graphic model taken from life. Aristotle's work "About the Soul" explains this model to us—these are the dust particles that are airborne and that become visible only in a ray of the sun. This analogy, which doubtless is the property of the founder of atomic theory, was the subject of lively discussion by later authors.

Thus, the considerations which guided the creators of the atomistic doctrine in Greece was a mixture of abstract speculations and inferences that were made on the basis of graphic analogies.

D. A. Varshalovich and M. I. D'yakonov, Quantum Theory of the Modulation of the Electron Beam at Optical Frequencies.

The modulation of a beam of electrons at radio frequencies has been investigated thoroughly both theoretically and experimentally and is widely used in radio engineering. So far as the optical range is concerned, the modulation was attained here only quite recently in the experiments of Schwarz and Hora[1]. A beam of fast electrons with energy E_0 = 50 keV passed through a thin film placed in the field of a light wave of a laser. The resultant modulation led to the appearance of luminescence with the frequency of the laser radiation when the beam impinged on a nonluminescent metal screen.

The appearance of the modulation in this experiment[1] can be explained in the following way. In the field of the laser wave the material of the film is polarized and surface charges develop. Through interaction with these charges the electron loses (or acquires) energy and momentum as a result of the stimulated emission (or absorption) of photons. These processes become possible only when an additional body—the film—is present. In a certain sense the surfaces of the film can be likened to a pair of grids to which has been applied a potential difference $U \sin \omega t$ varying at the optical frequency ω.



Dependence of the amplitude of the alternating electron-current component j_1 at frequency ω on the distance z. a) $V/\hbar\omega = 0$, the dashed line represents the classical theory, the continuous line—the quantum theory; b) $V/\hbar\omega = 10$, classical theory; c) $V/\hbar\omega = 10$, quantum theory.

In the classical description, when the electron passes through the film it is accelerated or decelerated, depending on the phase of the field at the moment of crossing the surface of the film. Electrons emitted from the film at various moments of time have various velocities. The fast electrons catch up to the slower ones which were emitted earlier. This results in their spatial bunching in such a way that the current density is modulated at the frequency ω and its harmonics. The electron velocities in a modulated beam are distributed in the interval from $v(1 - U/2E_0)$ to $v(1 + U/2E_0)$, where v is the initial velocity of the electrons. The continuous character of the velocity distribution leads to attenuation of the modulation at distances $z \gg l_0$, where $l \sim vE_0/\omega U$.

According to quantum mechanics, the electron which has passed through the film does not have a definite energy and momentum. Its wave function is a superposition of the states resulting from the emission or absorption of n quanta $h\omega$ ($n = 0, \pm 1, \pm 2, \ldots$). The modulation of the density and current of the electrons is due to the interference of these states. In this way, contrary to what the classical investigation gives, the distribution of the electrons by velocity in a modulated beam has a discrete character with $\Delta v \approx v h \omega / 2 E_0$. This discreteness leads to a situation wherein the dependence of the modulation depth on the distance behind the film z is essentially different from the dependence obtained by classical theory. It turns out that regions where the modulation is large recur in space periodically with a