THE PRE-EINSTEINIAN IDEAS OF EQUIVALENCE OF MASS AND ENERGY

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Summary

The idea that the heat substance "caloric" may have weight appeared with Nollet (1754). The Polish chemist Śniadecki suggested in the first half of the 19th century that imponderable substances like electric and magnetic fluid, caloric and light, the so-called "radiant beings" are the fourth state of matter which, admixed to ordinary matter change its solid into liquid and gaseous phase. He made the bold hint perhaps radiant beings owe their peculiarities to a specific substance.

The possibility of transforming motion into "weight" (mass) or chemical energy was not excluded by Mendeleev (1871) and Ostwald also alluded (1904) to a conception of matter as a complex of energy.

All these ideas remind us of the mass — energy equivalence announced by Einstein in 1905.

The word "energy" that became general in physics and chemistry in the 19th century, is of the ancient Greek origin. For Aristotle ενεργεια had the meaning of acting. Aristotle taught that the matter (ὕλη) is composed of four elements (στοχειον). Three of them—earth, water and air—represented the three states of matter; the fourth—fire transformed during the centuries subsequently into sulphur, flammable earth (terra pinguis), phlogistone and the substance of fire and light.

Therefore, we may not be astonished that Antoine Lavoisier in the eighties of the 18th century regarded caloric and light as chemical elements, the more so as chemical reactions were often accompanied by heat and light. By supposing that caloric is a fluid Lavoisier explained by its action the thermal dilatability of substances. He was, however, aware of that "the being of this fluid is only hypothetical to some extent" and that "strictly speaking we may not accept a caloric as a real substance; it is sufficient to suppose it would be a kind of cause of repulsion, that carries one molecule away from the other and let imagine the features in an abstract and mathematical way." [1].

The idea that caloric and light are chemical elements was widely accepted at the beginning of the 19th century and can be found in all chemical textbooks of that time. The Polish chemist Jędrzej (Andrew) Śniadecki (1768—1838) in his textbook "Początki chemii" (The beginning of chemistry) published in 1800

writes about "the repulsive power of the caloric that opposes to the Newtonian attraction between molecules." [2]

After the publication of the electrochemical works of Davy the electrical and magnetic fluids were also considered as chemical elements and forming with caloric and light a class of "inponderable elements", (e.g. in the textbook of Berzelius). A view expressed in 1754 by Nollet that the precision of our balances was too low to decide whether the substance of heat is "pesanteur" [3], was neglected at the beginning of the 19th century. Andrew Śniadecki considered, however, these four elements as fourth state of matter. He called them "a radiant state" and the inponderable elements—"the radiant beings". He argued that "these beings, when in a free state, when not bounded anyway, have an extremely high speed and disperse in a form of rays; and such a state I consider much more volatile and rare than that of gases." (This idea of "radiant state" has nothing to do with the radiant state proposed at that time by Faraday [4].)

According to Śniadecki originally all chemical elements are in solid state, their combination with a given quantity of caloric leads to the liquid phase. A further addition of caloric turns this liquid into gas [5]. In a paper written in 1815 Śniadecki considers, whether the radiant state of all "radiant beings" is their own quality or it may depend on the quality "of only one being that all other makes radiant." [6] In that case the combination of all substances that are in gaseous state "with a still greater quantity of caloric should change them into radiant state. This remains, however, a pure supposition till some experiment will verify or refute it".

In the ideas of the Polish chemist of "radiant beings" the notion of energy can easily be recognized. It should be noticed that before 1815 the quantitative term "energy" was already used by Thomas Young, but only in connection with rectilinear motion. Therefore it could not be used at that time for the quantitative characterization of the chaotic thermal motion. If we replace in Śniadecki's writings the term "radiant being" by the term "energy", his suggestion that all substances can be transformed into the "radiant state" is similar to the idea formulated by Einstein in 1905.

An analogous idea was expressed by Mendeleev in 1871, when he considered Prout's hypothesis. This hypothesis was rejected at that time, as almost all atomic weights appeared to be fractional numbers. In his paper Mendeleev wonders: "Even if we suppose that the substance of elements is thoroughly homogeneous, we can give no reason that n weight parts (Gewichtsteile) of an element or n atoms transforming into one atom shall give the same n weight parts... The weight could perhaps be caused by a special form of motion of the matter and there is no reason to reject the possibility of transforming such motion into a chemical energy or into another form of motion, when an elementar atom is formed." [7].

We must remember that a hundred years ago the term "weight" was used instead "mass", just as "power" and "motion"—instead "energy" and "momentum". In the above quotation we can thùs easily recognize the idea of mass defect. We know, however, that the reason of Mendeleev's considerations is erroneous. The Russian author could not pressume in 1871 the existence of isotopes. He admitted, however, the possibility of transformation of mass into energy, being aware—similarly as Śniadecki—that his supposition is not proved.

It is worthy of notice that in 1904, one year before the publication of the three famous Einstein's papers, the greates—at that time—antagonist of the idea of the corpuscular structure of the matter, Wilhelm Ostwald said during his Faraday Lecture held in the Royal Institution in London: "In the language of modern science I express these ideas (of atoms—R. M.) by stating: what we call matter is only a complex of energies, which we find together in the same place. We are still perfectly free, if we like, to suppose either that the energy fills the space homogeneously, or in a periodic or grained way; the latter assumption would be a substitute for the atomic hypothesis. The decision between these possibilities is a purely experimental question. Evidently there exists a great number of facts—and I count the chemical facts among them—which can be completely described by a homogeneous or non-periodic distribution of energy in space. Whether there exist facts which cannot be described without the periodic assumption, I dare not decide for want of knowledge; only I am bound to say that I know of none." [8]

In the history of science we can often meet ideas intuitively used many years before they were proved and formulated in an exact way. The idea of transformation of the corpuscular form of the matter into its energic form was, thus, one of them.

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