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Organon 4, 127-132

1967

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THE ROLE OF ANCIENT ATOMISM IN THE EVOLUTION OF CHEMICAL RESEARCH IN THE SECOND HALF OF THE 17th CENTURY

Discourses on chemical changes of matter carried on in the second half of the 17th century proceeded from a basis differing from the preceding by an essential topic: the tasks that men like Sennert and Jungius had set themselves had still been built up on universal natural philosophy. These tasks had mainly been limited to pointing out incongruities between the Scholastic doctrines and the emerging laboratory experience of chemists, and to interpreting anew these recent findings on the basis of the rediscovered ancient theories on corpuscles.

However, in the latter part of the 17th century there began to take root new concepts that had been developed by Galilei, Bacon and Descartes on the essence and tasks of science; these concepts contributed much to releasing chemistry from the fetters inflicted by natural philosophy, and to advance it to the status of an independent science with its own field of research. In 1663 Boyle put forward the opinion that the study of nature is not limited to yielding joy, "as it teaches us to know nature, but also as it teaches us in many cases to master and command it. For the true naturalist... does not only know many things which other men ignore, but can perform many things which other men cannot do, being unable by his skill not barely to understand several wonders of nature, but also partly to imitate, and partly to multiply and improve them." (*Some considerations touching the usefulness of experimental natural philosophy*, 2nd ed, Oxford 1664, p. 19.)

The essentially new message brought by these widened tasks to the evolution of chemical knowledge was that henceforth chemical experiments came to be acknowledged as the gauge by which the veracity of a new theory could be appraised. Thus one of the fundamental requirements demanded by Boyle at the beginning of this evolution was: to experiment, to observe, not to announce any theories without previously scrutinizing their respective results by experiments.

The task promulgated by Boyle, in particular in his writings on chemistry, was therefore much more comprehensive. Its essence was to interpret in a new way the qualitative transformation of matter, but at the same time to determine the essence of these qualitative transformations by chemical experiments. While these experiments merely represented an initial stage, yet they were of great importance for the further evolution of chemistry because, on the one hand, Boyle succeeded in developing the foundations of the qualitative analysis and, on the other, he managed by means of his unfailing and always repeatable experiments to point out very impressively the shortcomings of the scholastic doctrines and to procure a much wider appreciation to the atomistic theories, which he resumed and expanded.

In elaborating his theoretical assertions Boyle was able to use as basis the status attained in the first half of the 17th century by scientists like Jungius, by their resumption of the ancient doctrine on corpuscles. If, nevertheless, Boyle consigned a wider space to his critical attitude towards the scholastic doctrine on substantial forms, his prime intention must have been to overcome the mutual concessions entered into since the end of the 16th century between the theories of forms and those of corpuscles. He declared that: "Nothing in nature is composed of matter and a distinct substance, but man." (*The Works of the Honourable R. Boyle*, vol. I, ed. by R. Boulton, London 1699, p. 32.)

The cause of qualitative transformations of substances is not a change brought about by a form inflicted by exterior agencies, but—as had been stressed by Jungius at an earlier date—the mutual influence of the corpuscles of the partaking substances.

Boyle considered himself justified to this conclusion by reason of his practical experience, He wrote: "For, besides that which happens in the generation, corruption, nutrition and wasting of bodies, not only chymical resolutions, but microscopes discover bodies to consist of parts, very minute, and of different figures." (*The Works*, vol. IV, London 1700, p. 29.)

Even so, Boyle did not rely exclusively on Jungius' works. The treatises published by D. Sennert, P. Gassendi and R. Descartes, as well as Epicurus' and Lucretius' writings were known to him in their main parts. He gathered from these data whatever he deemed suitable for elucidating chemical processes, and he criticized the ancient atom theories merely because of their atheistic character.

As it is well known, in the evolution of his own doctrine on corpuscles Boyle started out from the following assumption: "It seems not absurd to conceive, that at the first production of mixed bodies, the universal matter ... was actually divided into little particles of several sizes and shapes, variously moved." (*The Works*, IV, p. 29.)

On the basis of certain geometrical conformities in their shapes, he supposed these minute corpuscles to be capable of forming corpuscle assemblages of divergent composition, in which the "posture", the arrangement of the various constituent corpuscles in the assemblage, should be distinguished from the "texture", the configuration the corpuscles assume in macroscopic bodies. In Boyle's opinion, "posture" and "texture" alone are the cause of the different qualities possessed by substances, and matter and motion are the only elements (*principia*) of the different bodies.

By thus consigning all material properties and their transformations to the two elements: matter and motion, Boyle came remarkably near to the ancient atom theories of Democritus, Epicurus and Lucretius. However, in chemistry of those times this reasoning represented an essential step ahead compared with the scholastic teachings of forms, because Boyle again considered the qualitative transformations of substances to be processes—processes mirroring an interior mechanism of exteriorly observed changes of qualities, identifiable by analytical chemistry. In this way a decisive point of issue for a further evolution of chemistry had been attained.

In consequence of the assumption of a world limited to matter and motion as elements of matter, there indeed had to be accepted an amendment in one of the main concepts of chemistry: in the notion of what is an element. This was so, because the concept of elements as was held by the ancient chemists—totally unmixed substances, different in quality, participating in the structure of the mixed substances —had to lose its sense, if one assumed corpuscles of a substance uniform in quality to be the ultimate simple constituents of chemical compounds. It is easy to prove that it was from this stage of knowledge, that Boyle began his famous criticism of the four peripatetic elements fire, water, air and earth, and the three spagyric elements sulphur, mercury and salt; even so, first he performed a great number of experiments and observations for proving the untenability of these ancient concepts. The final conclusions drawn by Boyle from these experiments—and it was principally M. Boas in her extensive investigations (M. Boas, *R. Boyle and seventeenth century chemistry*, Cambridge 1958) who pointed this out—were as follows: 1) there is no necessity to assume, that all mixed substances must always be built up of what are called elements, and 2) the so-called elements of the Peripatetics and the Spagyrians are no elements at all, no *principia* in the meaning of their definition. A further final conclusion, drawn by Boyle from his doctrine of corpuscles, was: there is no necessity at all of this kind of elements to exist. As to true elements, that is, final *principia*, these are particles, each different in shape and different in its motion, of common matter in general.

In spite of, or rather on the basis of, his critical attitude Boyle attempted a further step ahead, trying to evolve a new concept, that of a "chemical element"; this was an attempt which, unfortunately, he abandoned and which, later on, Lavoisier succeeded in carying to a successful end.

Again it was chemical experience that brought Boyle very near to conquering and to establishing this new concept of chemical elements by means of his corpuscle theory. From his chemical experiments he was aware—and this had already been stressed by Jungius—that there are certain arrangements of corpuscles which are very tenacious and durable; strong enough not to be split up by a variety of chemical transformations into their original composition. Among the examples mentioned by Boyle is the transformation of gold into goldchloride (*aqua regis*), or of mercury into mercurychloride, as well as the recovery of the metals in their original quality and quantity from these compounds. The relatively stable groups of corpuscles like gold and mercury Boyle called "clusters" or, at times, "primary concretions", ascribing their stableness to the minute size and to the particularly intimate union of the corpuscles forming these clusters. It was the concept of the existence of "clusters" of this type that brought Boyle very close to the new concept of a chemical element. In this context the "clusters" would have to be looked upon as chemical elements, that is, as substances into which mixed bodies are ultimately dissolved in chemical analyses, and gold and mercury would therefore have to be called chemical elements. The impulse towards this concept can indisputably be found in Boyle's *The Sceptical Chymist*; even so, Boyle confined himself to this, and rather he later abandoned this concept, again on the basis of experimental observations. These, however, happened to be misleading, because Boyle imagined, that by the use of a very strong solvent he had dissolved even gold "clusters" into their individual corpuscles and arranged these corpuscles to form a new metal. By reason of this and a number of further observations Boyle ultimately concluded, that no stable elements exist, that there is no need of recovering in the chemical analysis those substances that had been united by synthesis. Because, as Boyle argued: "hence it appears, that as the difference of bodies may depend meerly upon the schemes into which their common matter is put; so the seeds of things, the fire and other agents, are able to alter the minute parts of a body: And the same agents, partly by altering the shape or bigness of the constituent corpuscles of a body, partly by driving away some of them, partly by blending others with them, and partly by some new manner of connecting them, may give the whole portion of matter a new texture of its minute parts, and thereby make it deserve a new and distinct name." (*The Works*, IV, p. 118.)

Thus, the adoption and consistent evolution of the ancient doctrine on corpuscles by Boyle had diverse consequences in the further development of chemical research in the latter half of the 17th century: on the one hand, compared with the scholastic doctrines of forms and mixtures, Boyle's work constituted a decisive advance for the experimental possibilities of perception of matter and its transformations. Hence may be explained the strong reverberation incited by Boyle among his successors, like G. E. Stahl or, later on, Lomonosov who, as to himself, admitted that from the time he had read Boyle he was seized by the passionate desire to investigate the most minute particles (M. W. Lomonosov, *Ausgewählte Werke*, Berlin 1961, I, p. 9). On the other hand, however, Boyle's concept to ascribe the chemistry of substances to the physics of corpuscles, and to deny the existence of chemical elements led to a situation, in which chemists would have been unable to continue research on qualitative transformations of matter.

This explains the critical attitude adopted by chemists like N. Lémery or G. E. Stahl concerning Boyle's teachings.

Upholding the concept of the corpuscle theory, these chemists principally undertook to look for the "elements" which, in their opinion constituting stable matter, would represent objects of reference in the changes and transformations taking place.

Here again Lémery came very near to establishing the concept of a " chemical element", when in his arguments against Boyle he asserts: "Quelques philosophes modernes veulent persuader qu'il est incertain que les substances qu'on retire des mixtes, et que nous avons appelés Principes de Chymie, resident effectivement et naturellement dans le mixte: ils disent que le feu, en rarifiant la matière dans les distillations, est capable de lui donner ensuite un arrangement tout different de celui qu'elle avoit auparavant, et de former le sel, l'huile et les autres choses qu'on en tire."

And, at another place: "Le nom de Principe en Chymie, ne doit pas estre pris dans une signification tout à fait exacte: car les substances à qui l'on a donné ce nom ne sont principes qu'à notre égard, et qu'en tant que nous ne pouvons point aller plus avant dans la division des corps: mais on comprend bien que ces principes sont encore divisibles en une infinité de parties qui pourraien à plus juste titre estre appellées Principes. On n'entend donc par principes de Chymie que des substances separées et divisées autant que nos faibles efforts en sont capables". (*Cours de Chymie*, Onzième édition, à Leyde, 1716, pp. 5f.)

However, Lémery saw such *principia chymica*, or chemical elements, in certain of the ancient peripatetic or spagyric elements, and by this belief he again retreated a full step behind Boyle.

It was only towards the end of the 17th century that G. E. Stahl went a step ahead beyond J. J. Becher's experiments: in his efforts to explain the chemical processes during metal smelting, he discovered the essence of reduction and oxidation, ascribing this feat to his phlogiston. Afterwards, the change-over proceeding towards the phlogiston theory as general chemical theory did not constitute any break with the evolution reached up to then; it was not a resumption of occult qualities and scholastic beliefs as has often been maintained. On the contrary, it was the unavoidable evolution of Boyle's teachings, because Stahl's phlogiston theory was based, on the one hand, on Jungius' and Boyle's doctrine on corpuscles—as far as the mechanisms of chemical reactions were concerned—and, on the other, this theory was an attempt of perceiving in phlogiston a true chemical element, whose corpuscles partake in the reactions of oxidation and reduction and enter into the compounds of substances (I. Strube, "Die Phlogistonlehre G. E. Stahle in ihrer historischen Bedeutung", *Zeitschr. für Geschichte der Naturwissenschaften, Technik und Medizin (NTM)* 1961, 2).

In virtue of the resumption of the ancient doctrine on corpuscles and of its evolution by chemical practice and experiments, a new basis of research had thus been established towards the end of the 17th century. Starting out from this new basis, it became possible to further promote investigations of the qualitative transformations of substances. Yet required was, admittedly, the logical application of methods of quantitative examinations in order to be able to establish definitely those fixed items that science was looking for, the true chemical elements.