Chemia: Laboratorium myśli i działan [*Chemistry: Laboratory of Thoughts and Actions*], ed. by DANUTA SOBCZYŃSKA & PAWEŁ ZEIDLER, Uniwersytet im. Adama Mickiewicza w Poznaniu, Wydawnictwo Naukowe Instytutu Filozofii, Poznań, 1999, 218 pp. (ISBN 83-7092-049-7)

What is chemistry? Or more exactly, what is all included in chemistry? Is this science only a less-developed branch of physics? These and similar questions proceed like Ariadne's thread through this field of science as expounded in the Preface of this interesting book, in which scholars from several countries try to give answers.

One of the crucial problems stressed in the Preface is the lack of philosophy in chemistry, since this science originated by experiments and basically continues in the same way. As a result, chemistry, unlike physics and biology, did not develop its philosophy before the eighties of the 20th century! Instead, it was alchemy that produced its own philosophical background, though unfortunately erroneous, allowing for the existence of the dreamed transmutation of base metals into precious ones. It is a matter of discussion, however, whether or not to agree with the authors' claim in the Preface that alchemy was a prescientific form of chemistry. The relation between alchemy and chemistry deserves deeper discussion that is beyond the scope of this book and should be formulated rather carefully, because crafts significantly contributed to the development of chemistry too (a detailed picture is given by U. Klein: *Verbindung und Affinität*, Birkhäuser, 1994). Another point for discussion is the statement that the main goal of chemistry is the preparation of new compounds. Accepting this view would mean stressing chemical synthesis, but modern chemistry is about more problems than this. Biochemists, for instance, deal with transformations of known compounds and search for relations between different processes and for mechanisms stabilizing various compounds, such as proteins. We could also mention physical chemistry, with its very blurry borders (see J. Schummer: 'Physical Chemistry: Neither Fish nor Fowl?', in: *The Autonomy of Chemistry*, 1998), which yet influences other branches of chemistry. These comments on the Preface already document how broad and deep the problems appear when we approach chemistry from the point of view of philosophy. This book represents a valuable attempt to do so, and to discuss chemistry within broader limits, touching such diverse points as its language, its view of matter, and, most of all, its position among the natural sciences.

Some of the problems arise from scientists' conviction that they think logically, although gaps in their logic sometimes appear. According to R. HOFFMANN, V.I. MINKIN, and B.K. CARPENTER, who provide the example of Ockham's razor, it is sometimes useful to add philosophy to logic. (Their contribution to this book is a translation of an English paper published in *HYLE*, **3** (1997), 3-28.) As their starting point, they use a general formulation of this famous rule, according to which it is not necessary to look for complex explanations when a simpler one suffices. After a brief description of Ockham's life, they discuss particular cases of how his philosophical approach can be applied to chemical problems. As an example, they take the chemical reactions of tetraedric boron and discuss the proliferation of possible reaction mechanisms beyond necessity. In Ockham's razor they see a logical rule that suggests how to work with experimental data. Since the reaction mechanism can neither be directly observed, nor be strictly deduced from experimental data, chemists are required to apply Ockham's razor, but they need to do that with great care and at the right time. Like many other rules it has positive and negative aspects. According to the authors, Ockham's razor favors simpler models regarded as valuable, whereas is also a conservative tool and may prevent scientific innovations. A final citation from Einstein that everything should be done as simply as possible reminds the present reviewer of Einstein and Smoluchowski's brilliant solution of such a complicated process as Brownian motion.

"Chemistry is the scientific study of the properties, composition, and structure of matter, the changes in structure and composition of matter, and accompanying energy changes", according to the definition given by a classic encyclopedia (*McGraw-Hill Dictionary of Scientific and Technical Terms*, New York 1989). If we add to this definition that chemistry widely uses physical values to describe its objects, it is no wonder that chemistry is often reduced to a certain less-exact branch of physics. P. ZEIDLER discusses the issues of reductionism and to what extent chemistry is a theoretical science. Reductionism has its roots in the mechanistic approach to natural sciences. In chemistry, however, experiment is of extraordinary importance. It was exactly this aspect of chemistry from which further arguments for its less-exact level were derived, if one accepts as exact only such science that has its theoretical apparatus expressed in mathematical terms. Zeidler discusses in detail what chemists consider as chemical theory. Such theories appeared early, the first of them being the phlogiston theory; later, other theories were formulated such as the theory of chemical structure, the Brönstedt theory, *etc*. In spite of this and because of an insufficient mathematical formulation, chemistry was not considered to be a theoretical science. According to Zeidler, it seems that basic laws in chemistry are unusually rare. At a closer look, Brönstedt's theory and others are actually definitions, in this case of an acid and a base. With the appearance of quantum mechanics, the reduction of chemistry to physics revived anew, but it should be remembered that quantum mechanical calculations use only approximate approaches in chemistry. They cannot give, for example, an unambiguous conception of a chemical compound. In Zeidler's opinion the reduction of chemistry to physics is in a crisis now. He supports this claim by views of I. Hacking, according to whom the classical division of theoretical and experimental research should be replaced by a trio: considerations, calculations, and experiment. Zeidler illustrates this approach with the example of organic synthesis, not without warning that a reaction mechanism cannot be deduced from available experimental data. Models are important in chemistry, but experiment must follow. It is exactly the development of new experimental methods, particularly spectroscopic ones, that makes it possible to examine chemical compounds in more detail. There is, however, an important point stressed by Zeidler: in all these approaches, microscopic structures are described by macroscopic values, for example by the distances between spectral lines. Simultaneously, a new question appears: can all chemical effects related to the structure of a compound be deduced from the theoretical model of this structure? Zeidler suggests another model that is also theoretical but in a different way than the classical quantum mechanical one. This new theoretical approach employs a dynamic model of a compound that depends on the experimental technique used. In this model, the concept of the structure of a compound becomes a metaphor that does not strictly represent any stable property of the given compound. According to Zeidler, generalizing in chemistry differs from generalizing in physics, because of its approximate character. Since chemistry basically differs from physics, especially because of the different methodologies, he suggests that we should not call chemistry a physical science.

Interesting conclusions can be drawn from seemingly unrelated processes. In her contribution, E. ZIELONACKA-LIS gives as example the relation between the time necessary for drying clothes on a line and the distance a plane needs for its take-off. The explanation of this phenomenon is causal and statistical: the higher the humidity of air, the more time do clothes need to dry, and the longer is the distance the plane needs to take off. There are also causal and probabilistic explanations. If, for instance, a 30 000 year-old bone is found in Alaska, in a region inhabited 12 000 years ago, all explanations of this finding will be causal and probabilistic. These model examples are based on theories of explanation in science by W. Salmon, and C. G. Hempel and P. Oppenheim. Once these approaches are applied to chemistry, problems appear however. Especially in Salmon's approach, Zielonacka-Lis misses the capacity to consider problems of chemical kinetics and of the question of the reaction medium. Especially with the advent of modern methods allowing the study of kinetics on the femtosecond level, complicated reaction mechanisms can be resolved into simpler individual steps (do we not arrive close at Ockham's razor?). She concludes that Salmon's views can be applied to empirical categories of chemistry, such as the chemical compound, but not as easily to the microcosm of this science, such as the mechanisms of chemical reaction and the structure of a chemical compound.

The role of instruments in chemistry is the topic of the contribution of D. SOBCZYŃSKA. In her introduction she discusses a limit that cannot be reached – the reconciliation of empiricism and theory in sciences. The focus of her paper is on chemical analysis and synthesis and the lasting values of instruments, considered as materialized form of scientific thinking. In a brief historical survey, she considers the influence of alchemy and the chemical crafts on the development of instrumentation, as well as the fact that the first methods used were on physical basis (filtration, distillation, etc.). As for the uniqueness of chemistry among the natural sciences, she explains that, in the form of alchemy, it was the only one that was performed in a laboratory. Alchemy proposed theories, but its real contribution was in practice. According to Sobczyńska, analysis and synthesis are two crucial processes in chemistry that form one whole (here, the ancient concept of yin and yang may occur to the reader) expressed in Guldberg-Waage's law, as the majority of chemical reactions reach equilibrium. Analysis has a longer tradition that originated in the analysis of precious metals in ancient cultures. We can recall the ancient process of cupellation (see, for example, J. O. Nriagu, *Journal of Chemical Education*, 62 (1985), 669-674). Modern analysis appeared with Lavoisier. It should be recalled here that the discoveries of the chemical elements were one of the driving forces of chemical analysis that received firm foundations later in the works of Ostwald, Arrhenius, and others. Instrumental analysis markedly developed in the twenties and thirties of the 20th century. The present reviewer would like to add that the polarograph constructed by Heyrovský (and Shikata, whose name almost disappeared from the literature) was the first instrument with an *automatic registration* of data. Instrumental analysis was a germ of chemical thinking. From this point of view, Sobczyńska discusses its development as a scientific revolution according to concepts provided by T.S. Kuhn, I.B. Cohen, and I. Hacking. On the other hand, she regards synthesis as consisting of two main directions. The first, older one was based on the synthesis of compounds occurring in nature, which started with Wöhler's synthesis of urea. (The role of this synthesis in the historico-philosophical context was recently analyzed by P.J. Ramberg: *Ambix*, 47 [2000], 170-95.) The second one is the preparation of new compounds not occurring in nature, for example synthetic polymers. That branch makes chemistry unique. According to Sobczyńska, chemistry was always experimental and continues to be the example of experimental science.

A second contribution devoted to the instrumental side of chemistry is the Polish translation of the paper by D. ROTHBART and S.W. SLAYTON "The Epistemology of a Spectrometer" (*Philosophy of Science*, 61 (1994), 25-38).

The formulation of law of conservation of matter was one of the turning points in the history of chemistry. According to E. PIETRUSKA-MADEJ, this law has traditionally been ascribed to Lavoisier, and its first formulation appeared in his *Traité élémentaire* in 1784. However, Lavoisier mentioned the law almost in passing; he neither derived it theoretically nor supported it by empirical arguments. Instead, he wrote about this law as if he were already accustomed to taking it into account. Pietruska-Madej supposes that it was precisely this law that was the driving force of Lavoisier's former experiments, for example the burning of tin in a closed vessel (1774). At least in this experiment, Lavoisier tacitly accepted the law as valid. However in the same way, the law was accepted much earlier, as in van Helmont's famous experiment with a willow tree. This scholar anticipated constancy of masses of the original substances and products, of earth and wood. The author brings further examples to support her view: Boyle, who also burned tin; and the phlogiston theory. Likewise, Proust's law of definite proportion from 1797 had its predecessors. According to Pietruska-Madej, older works can be found that also tacitly anticipated this law. It should be added perhaps that Roger Bacon (?1214-92) arrived at the verge of this discovery (see N. A. Morozov: *V poiskach filosofskogo kamnya* [*In search for the Philosopher's Stone*], Moscow, 1909, p. 50) when he concluded that bodies can be formed in certain proportion. He apparently drew this conclusion by supposing the existence of two different compounds of sulphur with mercury. It is not clear whether this was pure speculation (although a correct one) or a result of some experiments, as the compound Hg_2S does actually exist, but is unstable at room temperature. To sum up, the author judges that there are more laws in chemistry that were tacitly anticipated in the past, before they were 'officially' formulated. The question is whether this was the case in other sciences as well. At present, there is not enough material to provide an answer, but it is a research direction worth studying.

In his two papers, J. KONARSKI discusses today's knowledge about the shape of chemical compounds and problems connected with understanding structure on the level of atoms. Shape is first what we use when we want to distinguish things and to identify them. This approach was then transferred to a world on the atomic level; the length of chemical bonds or their angles sometimes achieve almost absolute importance. However, this leads to a false picture of the atomic world, ruled by Heisenberg's principle of uncertainty and energy changes in quanta. In Konarski's view, the only reliable information about the world on this level can be obtained by means of energy, whereas all subsequent conclusions depend on the model chosen. For a reliable description of a chemical compound, the distances between atoms cannot be used because they depend on the energetic state of the compound. In other words, the interpretation of data about matter on a microscopic level must be done with caution. Konarski's second paper, about the crisis of reductionism, continues this line of thought: a macroscopic phenomenon can result from many microscopic ones. This leads to the crucial problem as he states it: *"we can have many models, but there is only one reality"*. His final discussion of problems of reductionism in the biological sciences is only brief, but opens a very important field of further research, especially when the theory of chaos gains firmer ground.

In her paper, A. KRUPSKA draws attention to dissipative structures in light of Prigogine's and Popper's views. She provides an overview of problems and the present state of knowledge of such structures, with special emphasis on biological systems. The key problem was the treatment of systems far from thermodynamic equilibrium where classical thermodynamics fails. These are exactly the systems with dissipative structures and the ability of self-organization. As stressed by the author, dissipative structures can evolve on different levels of the organization of matter, from classical Belousov-Zhabotinsky's reaction to complex biological systems. She refers to mathematical models of dissipative structures according to Prigogine and Turing. The final discussion in which Krupska asks to which extent Prigogine's theory is generally valid is very interesting. Which was formed first, nucleic acid or a protein? According to her, the two processes could have happened simultaneously provided that suitable chemical gradients existed in conditions of thermodynamic instability. As she finally points out, Prigogine's theory has limits of application. It works well for most chemical, biochemical, and biological systems, and even for biological communities, but not for human societies.

A Polish translation of J. SCHUMMER's "Towards a Philosophy of Chemistry" (*Journal for General Philosophy of Science*, **28** (1997), 307-336) ends the series of papers.

On the subsequent fourteen pages there is brief information about research in the field of philosophy and methodology of chemistry, a bibliography of works by Polish authors on the philosophy and history of chemistry, a list of Polish translations of foreign books on this topic, and brief notes about the authors who contributed to this book.

The reviewed book belongs among valuable attempts to look at chemistry from a point of view different from the 'exact-scientific' one. Several questions are posed and the reader will probably not always fully agree. However, unquestioning agreement, to the effect of stopping any discussion, is not the aim of such a work. Instead, it is just discussion that should be stimulated. In that point lies the importance of this book. The work would be especially interesting to readers in other former Communist countries, where philosophy was only one-sided and in some places almost ceased to exist. While philosophy of any science is important, in the case of chemistry, philosophy also touches a particular sensitive point concerning its repeated subordination to physics. These two sciences are in no way totally independent. Chemistry has a very complex origin, with roots in alchemy, crafts, and early chemical experiments, but also in physics. It is important to anchor chemistry among the spectrum of natural sciences as an individual with characteristic features. The reviewed book brings a lot of arguments that help solve this problem.

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