Book Review

Hinne Hettema: *Reducing Chemistry to Physics: Limits, Models, Consequences*, Groningen: Rijksuniversiteit Groningen, 2012, xxvi+453 pp. [ISBN: 978-1475120912]

by Olimpia Lombardi

The many-faced relationship between chemistry and physics is one of the mostly discussed topics in the philosophy of chemistry. Hinne Hettema conceives this relationship as a reduction link, and devotes his book to defend this position on the basis of a 'naturalized' concept of reduction.

The book (the author's doctoral thesis) consists of a first chapter and three parts. The first chapter, entitled 'Reduction: its prospects and limits', offers an overview of the notion of reduction from a historical perspective, from 19th-century positivism through Nagel's *locus classicus* to certain contemporary reductionist proposals. Here Hettema defends a liberal and 'naturalized' Nagelian reduction, which admits a number of modifications that weaken the original scheme. From this viewpoint, he considers the relation between reduction and unity of science, and critically discusses certain recent anti-reductionist positions in the philosophy of chemistry.

The first part, named 'Limits', begins by analyzing two of the central concepts involved in traditional discussions of reduction: chemical bond and molecular structure. After the questionable claim of the equivalence between the Valence Bond and the Molecular Orbital theories, Hettema argues for understanding chemical bond in terms of the pair idealization/concretization: while both theories give different idealized descriptions of the molecule, they converge toward the same quantitatively more accurate description through concretization. In turn, based on the distinction between molecular shape and molecular structure, he criticizes the non-reducibility of molecular shape to physics. In a second approach, he argues for the explanatory role of quantum chemistry by stressing the role of certain 'enabling' theorems, which, although stemming from quantum mechanics, have a unique application in chemistry. Finally, he reconstructs quantum chemistry as a Lakatosian program that can consistently integrate *ab initio* calculations and semi-empirical methods.

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The second part, named 'Models', is devoted to a structuralist reconstruction of quantum chemistry. To that end, the author first introduces the main concepts of the structuralist approach (following the 1987 canonical work of Balzer, Moulines & Sneed, *An Architectonic for Science: the Structuralist Programme*), with a focus on the notion of reduction in this framework. Then he proposes a structuralist reconstruction of two versions of quantum mechanics, a 'simple' one and a 'complex' one, and proceeds to reconstruct *ab initio* and semi-empirical quantum chemistry. Facing the relationship between quantum mechanics and quantum chemistry, Hettema concedes that the structuralist view of reduction in terms of subsets of structures is not adequate for this case. Instead the reductive relation has to be conceived as a structural link that connects quantum chemistry with quantum theory in a non-smoothly continuous way. He then applies that approach to the reduction of the Periodic Table and of the chemical bond (as representative theories of chemistry) to quantum chemistry. The conclusion of this task is that reduction is achieved by a bundle of partial or 'local' structural links, which require not only different kinds of idealizations and approximations, but also a transformation of the reducing theory by means of assumptions that are external to and frequently even at odds with the reducing theory itself.

The two chapters of the third part, 'Consequences', focus on ontological problems. In the first of them, Hettema argues that certain recent debates on the notion of orbital in the philosophy of chemistry are based on a misguided interpretation of orbitals in spatial terms; according to the author, chemists and quantum theorists alike are committed to 'orbitals' *qua* mathematical functions. The second chapter of this part is the most philosophical and, at the same time, the weakest section of the book. Here he addresses the traditional problem of the reference of theoretical terms in terms of a relation of 'grounding' that is not clear enough: although initially defined as a metaphysical relation between ontological items, later grounding is transformed into an epistemic relation between concepts or even between inter-theoretic links and theoretical terms. In this chapter he also incorrectly claims that the notion of ontological reduction would be peculiar to the philosophy of chemistry. Moreover, he proposes a Kantian-rooted notion of chemical element, derived from a 'peculiar' reading of the Kantian theses that deprives them from their philosophical strength by assuming the identification between the noumenal realm and the unobservable domain.

Overall, the book is a valuable work about the relationship between chemistry and physics, since it discusses many aspects of the problem by combining chemical knowledge and philosophical arguments in adequate proportions. In particular, philosophers of science involved in the structuralist program will find here an interesting case of reconstruction that takes into account the subtleties of real world science. From a more general stance, the main contribution of the structuralist and the Lakatosian reconstructions is

that they accurately bring to light the assumptions needed to link chemistry, quantum chemistry, and quantum mechanics, allowing the reader to take an own position about the nature of those links.

There are, however, certain points that might give rise to perplexity. One of them is the general conclusion that is expressed by the last sentence of the book: "The reduction of chemistry to physics is in this sense indeed a paradigm case for the notion of reduction" (p. 410). However, for reaching this conclusion, the book has driven us through a long way fraught with the intricacies of the supposed reduction. The reductive links do not supply a global reduction but only local and partial reductions of particular theories of chemistry. They introduce relevant idealizations and approximations that establish loose and non-continuous connections between theories. They even draw concepts out of their context and re-use them in a manner inadmissible to the theory to which the concepts originally belong. These links provide a liberal notion of reduction, which could even be made compatible with non-reductionist positions. But once the concept of reduction has been relaxed in such a way, we are entitled to ask why the relationship is still called 'reduction' instead of 'inter-theory link', and how to justify Hettema's insistence on conceptualizing this kind of loose links as reductive in the Nagelian sense.

Perhaps the answer to these questions can be found in the 'naturalistic' or 'pragmatic' stance adopted by the author, according to which "the reduction between chemistry and physics should be the hallmark of what we would expect a successful reduction to accomplish" (p. 8), and "reduction conditions are what has to be proven in actual cases of reduction (such as the one from chemistry to physics), rather than imposed from the outset" (p. 4). However, somebody might consider that this move puts the cart before the horse: the reduction of chemistry to physics is postulated from the very beginning, and on this basis the notion of reduction is adapted and made 'flexible' as much as needed to agree with the original postulation. This strategy leaves no room for conceiving different kinds of inter-theory relations, which may lead to a non-reductive unity of science.

Summing up, this book will be very fruitful for those interested in understanding the subtlety and complexity underlying the loose and indirect links that interconnect chemistry, quantum chemistry, and quantum mechanics. It is a work that definitively deserves to be read, since it supplies a wide spectrum of interesting arguments – especially for non-reductionists.

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