Carsten Reinhardt: *Shifting and Rearranging – Physical Methods and the Transformation of Modern Chemistry*, Sagamore Beach, MA: Science History Publications, 2006, 428 pp. [ISBN 0-88135-354-X]

This large monograph by historian of science Carsten Reinhardt (now University of Bielefeld) is his *Habilitation* thesis (at the University of Regensburg), which is still a prerequisite to gain the *venia legendi* at several German universities. *Shifting and Rearranging* consists mainly of six case studies referring to the works of Klaus Biemann, Carl Djerassi, Richard Ernst, Herbert Gutowsky, Fred McLafferty, and John Roberts. Biemann, Djerassi, and McLafferty are chosen because of the tremendous impact they had (mainly) on mass spectrometry, whereas Ernst, Gutowsky, and Roberts are well-chosen examples from the field of nuclear magnetic resonance spectrometry. The author presents his case studies in an interwoven manner rather than putting together some more or less similar biographies. In five main chapters he tells the detailed stories of how these scientists accommodated and assimilated the new physical instrumental methods and, at the same time, contributed to changing the whole enterprise called chemistry. Already in the preface the author observes: Chemistry's "object of examination, the chemical substance, was transmuted into abstract structure; its most important method, the chemical reaction, was supplemented by physical methods; and its practitioner, the chemist, was partially displaced by technical instruments" (p. vii). The first thesis of this sentence, however, is not really surprising. We can find this kind of abstraction much earlier than the author claims, already before the mid-20th century, for example, in the acceptance of atomism in chemistry which began in the early 19th century. Also text-book characterizations of chemistry indicate a dramatic change: Starting from the science of substances and their changes at least in the 18th century, there is a reasonable tendency to shift the chemical core to the 'abstract' microphysical realm already well before 1950. Hence, the mentioned abstraction, which can be considered chemistry's conceptual shift from substances to molecules, is a movement which is obviously independent from what some historians call 'instrumental revolution'. Although he mentions it and quotes the relevant sources, Carsten Reinhardt is obviously professionally reluctant to use the latter concept throughout his book.

As to the second part of the quote from the preface, intriguing questions for both history and philosophy of chemistry can be raised, such as 'Has chemistry been reduced to physics by instrumental spectroscopy?' Reinhardt is very clear about that and similar questions: "This book describes the transfer of instrumental research methods from physics to chemistry […] To make instruments chemical – in devising useful methods for chemists – was research in its own right, and a strategy of chemists for creating disciplinary space" (p. 1).

The author is extraordinarily clear with respect to his methodology as well. He identifies five main topics – which he calls different dimensions of scientific methods – that need to be examined in the framework of his endeavour (pp. 12-15): (1) Making of methods in the laboratory; (2) adaptation of chemical concepts; (3) standardization and teaching; (4) the university-industry nexus; and (5) social organization. All these issues are carefully addressed in the central chapters and summed up in the concluding chapter (*The Spectrum of Methods*, pp. 357-388). Besides the common published sources of 'ready and done' science – the use of which is restricted for a historical investigation on empirical and instrumental practice – Reinhardt uses material from private archives (*e.g.* Biemann, Ernst, Roberts) and university collections (*e.g.* Stanford,

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MIT, Harvard) as well as interviews, seven of which he conducted by himself.

We take a brief but exemplarily look at two of the cases. First, the word 'rearranging' of the title is borrowed from what has become famous as 'McLafferty rearrangement' in chemistry. The latter is a spontaneous stabilization reaction of certain cations in evacuated instruments (mass spectrometers) with a moving H-Atom via an assumed hexagonal intermediate structure, yielding molecules and radical-ions that are typical in pattern but different from the usual decay of molecular ions. Fred McLafferty had been with Dow Chemical Co. from 1950 until 1964 after which he went to Purdue University (and 1968 to Cornell). During his crucial time in industry, he measured and collected hundreds of mass spectra and strived for their interpretation. In the early 1950s he recognized the regularity of decompositions which carries his name (pp. 103-112). He interpreted it pragmatically, *i.e.* he considered the reaction in the mass spectrometer to be like usual chemical reactions anywhere else. This is exactly an example of what Carsten Reinhardt means by 'shift': The transfer of 'common' chemical language – used for describing the properties and reactions of empirical substances – to the field of 'chemistry in the instrument'. However, this shift not only affected chemistry as a discipline but also the entire instrument family: "A mass spectrometer, even if technically unchanged, encoded different theoretical meanings for physicists measuring nuclear forces in the 1920s, industrial chemists collecting compound data in the 1940s, and natural product chemists disentangling molecular structures in the 1960s" (p. 19).

The second story of the career of the Swiss NMR-pioneer Richard Ernst (Nobel Prize 1991) is particularly intriguing and telling in this context (chapter 6 with the funny title "A Spin Doctor in Resonance"). Ernst was educated as a chemist at ETH Zurich to which he returned as assistant professor in 1968 after a stint with Varian Associates, Palo Alto, from 1963 on. The most important of his developments are Fourier-transformed NMR and two-dimensional NMR. Reinhardt describes Ernst as a methods-oriented scientist. Though he and his co-workers also worked on applications, the instrumental part of his scientific work had by far the highest priority. He took up this style of work during his time as Ph.D. student with theoretician (and philosopher of chemistry) Hans Primas at Zurich. Reinhardt chooses the model of a middleman to describe Ernst's situation: "Method makers, acting as mediators, were crucial actors in the process. The focus of this book is on the middleman cultures of physical instrumentation in chemistry. In cultural anthropology, middleman cultures are minorities in which a disproportionately high number of individuals is engaged in trade. […] Method makers attached new meanings to technological objects, and their benefit rested on the wide use of them in scientific communities. For doing so, they needed standing in the importing communities as well as allies in the exporting cultures" (p. 21).

In *Shifting and Rearranging*, Carsten Reinhardt kindly (and almost implicitly) reminds the community of philosophers of chemistry not to draw too adventurous conclusions by applying their respective model, concept, or idea to primary literature alone. He claims that many areas of chemistry (physical organic chemistry, analytical chemistry, organic chemistry, and the like) in the investigated period (and, we may add, ever since) are best characterized by the activities of method makers and assimilators of chemical concepts: "Competence in methods was the word of the day, and carried forward by a new type of scientist. Neither just experimentalist nor theoretician, an expert in methods worked across many fields, ranging from physics to chemistry and the bio-

medical sciences" (p. 360). However, questions like whether or not chemists have been methodically pragmatic already before the instrumental revolution, have to be left open to further investigations.

Without any doubt Reinhardt's thesis that physical methods like mass spectrometry and nuclear magnetic resonance have been converted into chemical methods and saved the disciplinary autonomy will sound embalming to the (virtual) anti-reductionism movement, although the non-reducibility of methods is a widely accepted assumption in philosophy of science.

There are some minor formal drawbacks. Unfortunately, there are no references to the footnotes; the German transcripts of the quoted passages from the interview with Ernst in the footnotes are somewhat awkward (whereas a quotation of Bachelard has been left in French, p. 11); and the index apparatus refers to companies and names, whereas a subject index, which would be helpful to work with such a large and dense volume, is missing.

Carsten Reinhardt has delivered a particularly useful and well-written study. This book will become nothing less than a standard in the history and philosophy of chemistry.

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