Book Reviews

Ars Mutandi: Issues in Philosophy and History of Chemistry, ed. by NIKOS PSARROS & KOSTAS GAVROGLU, Leipziger Universitätsverlag, Leipzig, 1999, iv + 190 pp. (ISBN 3-933240-89-1)

Ars Mutandi is a compilation of papers presented at the International Conference on the Philosophy of Chemistry and Biochemistry and Adjacent Historical Problems held in Athens, Greece during April 1996. The proceedings are comprised of seventeen papers submitted by participants from eleven different countries and may be divided into seven different sections; Falsificationism and Chemistry (2 papers), Chemical Epistemology and History of Chemistry (2 papers), Shaping Chemistry (4 papers), Chemical Entities (3 papers), Chemistry and Quantum Mechanics (2 papers), Chemistry and Its Neighboring Sciences (3 papers) and Chemical Heritage of the Ancient Greek World (1 paper). This wide variety of topics provides the reader with a great deal to contemplate and ponder.

Ars Mutandi begins with a brief, four page, Introduction by the editors. NIKOS PSARROS and KOSTAS GAVROGLU provide the rationale behind holding an international conference on the philosophy and history of chemistry and discuss the increased level of attention the field is deservedly receiving. My first reading of the Introduction caused significant concern because of the poor level of English. Fortunately, the papers are well written and highly polished. Hopefully, the Introduction will not scare any potential readers away, as it is not indicative of the proceedings as a whole.

The first section, Falsificationism and Chemistry, involves F. MICHAEL AKEROYD (Bradford, UK) and MAUREEN CHRISTIE (Melbourne, Australia) taking opposite sides of Popper's idea of falsificationism. Akeroyd argues in support of falsificationism in his paper "Popper and Biochemical Sciences" with support from examples involving cell-free fermentation, pneumococcal transformation, thermophilic bacteria and the isolation of enzymatic RNA. Akeroyd concludes his argument that "a large portion of the history of biochemistry supports the position of Karl Popper" (p. 4).

Christie take the opposite view and argues against Popper's "asymmetry between confirmation and falsification" (p. 7) in "Falsification and Direct Confirmation in Scientific Theory Adoptions". She bases her argument on an analysis of the Antarctic ozone hole and three competing explanations; the presence of chlorinated compounds, a major climatic change, or increased solar activity. Analysis of data resulted in the first hypothesis being adapted because of the strong negative correlation between the ClO and O_3 mixing ratios. To Christie, this example refutes Popper's ideas because the first hypothesis was adopted through positive reaffirmation and not falsification. The problem with her argument is that while valid for the initial comparison of competing hypotheses, the strong negative correlation does not prove the first hypothesis to be correct: it simple makes it more tenable than the competing hypotheses. With the limited resources available for studying the source of ozone depletion, focusing on the strongest hypothesis was the only viable path to follow.

The second section, Chemical Epistemology and History of Chemistry, includes contributions from URSULA KLEIN (Berlin, Germany), "Do We Need a Philosophy of Chemistry?" and MICHAEL ENGEL (Berlin, Germany), "Naturphilosophische Überzeugungen als forschungsleitendes Motiv – Die asymmetrische Synthese von Pasteur bis Bredig". Klein's analysis of chemistry's progress from focusing on a material's physical properties "into a coherent system embracing chemical substances and their transformation" (p. 25) nicely outlines chemistry's growth from a descriptive, into a synthetic, endeavor.

In an effort to see German reintroduced as a language used in international conferences, Engel's contribution to the proceedings are in his mother tongue, German. While this is a noble cause, he has done his scholarship a disservice by limiting its audience to those who read German, or those willing to find someone to translate. The consequences of his actions are quite severe for young scholars in North America, as many doctoral programs have eliminated their foreign language requirements. As a result, many readers will simply skip Engel's contribution. As the editors state in their Introduction, "English is in fact the contemporary *lingua franca*, which means that it is no more the possession of only a single nation, but of the humanity as a whole" (p. ii).

The section on Shaping Chemistry contains the greatest number of contributed articles and also incorporates the greatest variety of topics. GENNADIY KOPYLOV (Moscow, Russia) discusses development and structure of the natural sciences in "The Engineering World and Chemistry: An Outline of the Research Programme"; DANIEL ROTHBART (Fairfax, USA) discusses the convolution of experiment and theory in his "The 'Design' of Nature through Chemical Instrumentation"; JOSEPH EARLEY, SR. (Washington, USA) comments on "the question of compound individuals" (p. 75) in "How Do Chemists Know When 'Many' Become 'One'? Can Others Do It Too?"; and REIN VIHALEMM (Tartu, Estonia) argues that chemistry is distinct from both physics and biology in "Can Chemistry Be Handled as its Own Type of Science?"

Rothbart's article provides an excellent example of how philosophical issues can be explored in the chemistry curriculum. For example, his statement, "When data are acquired, abstract theoretical judgements are not all removed from the experiment; rather, such judgements are channeled through the instrument to solidify the formulation of the specimen's universal character. Through the mediation of the instrument, the physical real is united with the conceptual real." makes a great discussion topic for an undergraduate instrumental analysis course.

The forth section, Chemical Entities, includes "A Conceptual Profile for Molecule and Molecular Structure" by EDUARDO MORTIMER and LUIZ OTÁVIO AMARAL (Belo Horizonte, Brazil); "Fullerenes: The Philosophical Aspects of their Discovery" by DANUTA SOBCZYŃSKA (Poznań, Poland) and "Are there Laws of Nature in Chemistry?" by NIKOS PSARROS (Marburg, Germany). The first of these contributions explores the interesting question of what is meant by 'molecule' or 'molecular'. Specifically, the example of PF_5 – a compound without a unique structure – and physical properties such as melting point, dielectric constant and dilation are discussed. Again, this is a rich source of material for discussion in undergraduate chemistry classes.

Sobczyńska's article on the transformation of fullerenes from a theoretical entity to an experimental one is a wonderful example of history in the making. Finally, Psarros' piece provides a wonderful comparison between the results and consequences of an experiment.

The contributions of VINCENZO AQUILANTI (Perugia, Italia) and VALERIA MOSINI (Rome, Italia), respectively entitled "Sceptical Chemists in a World of Atoms and Quanta" and "Wheland, Pauling and the Resonance Structures", constitute the section on Chemistry and Quantum Mechanics. Both authors have done an excellent job of dealing with chemistry issues and not falling into the philosophy of physics paradigm. If the reader were still undecided with respect to the need of philosophical studies of chemistry at this point in the book, Aquilanti puts those fears to rest when he states, "no expert in quantum mechanics can take the place of a chemist whose problems arise from his direct experience of substances under specific experimental conditions" (p. 120).

Similarly, Mosini's comparison of realist and instrumentalist views in her discussion of resonance structures underscores the significant contributions that philosophical studies of chemistry offer. This article also contains a wonderful comparison of the Valence Bond and Molecular Orbital theory's explanations of resonance structures during the first part of the 20^{th} century that proved enlightening and a joy to read.

The section on Chemistry and Its Neighboring Sciences contains three articles, "*In vitro* vs. *In vivo*: The Problem of Justifying the Biological Relevance of Biochemical Studies" by ROGER STRAND (Bergen, Norway); "Research Practice of Modern Bioinorganic Chemistry and the Erotectic Conception of Explanation" by EWA ZIELONACKA-LIS (Poznań, Poland); and "A New Kind of Chemical Computer-based Chemical Conversions" by LECH SCHULZ (Poznań, Poland). While each of these discussions is specific to a chemistry sub-discipline, they each have wider implications upon further examination. For example, Stand's discussion of the relevance of *In vitro* testing in an *In vitro* world can easily be extended to the realm of computational chemistry where the results are only as accurate as the theory. As computational speed and power continues to grow and we become increasingly dependent upon simulations of the virtual-kind, these issues will come to the forefront of philosophical discussion.

The final section, Chemical Heritage of the Ancient Greek World, contains a single contribution entitled "Experimental Techniques and Laboratory Apparatus in Ancient Greece" by EVANGELINA VARELLA (Thessaloniki, Greece). While we often think of ancient Greece as the realm of philosophy and the antithesis of science, Varella's excerpts from the ancient literature highlight the presence, and importance, of a variety of experimental techniques. Although a valid argument may be made that the examples are of technology, not science, it is interesting, and sobering, to read laboratory procedures from a time past.

In conclusion, *Ars Mutandi* is a worthwhile addition to a personal, or institutional, library. The issues discussed are varied with something for everyone who is interested in the pertinent issues in the philosophy of chemistry. Numerous articles lend themselves to inclusion in the undergraduate curriculum as discussion pieces. This is an important aspect since a growing awareness of philosophical issues will only occur if we expose our students to their existence.

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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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JUERGEN HEINRICH MAAR, *Pequena História da Química. Uma História da Ciência da Matéria. Primeira Parte: Dos Primórdios a Lavoisier* [*A Short History of Chemistry. A History of the Science of Matter. First Part: From its Beginnings to Lavoisier*], Editora Papa-Livro, Florianópolis, 1999, 848 pp. (ISBN: 85-7291-049-2)

Juergen Heinrich Maar offers a "short" overview of the history of chemistry from its inception to Lavoisier. It is a book written in Portuguese by a Brazilian chemist. The author begins by looking at the non-Greek origins of chemistry, focusing on Hindu and Chinese contributions (Chapter 2). He pays particular attention to its practical components developed around the art of metallurgy, ceramics, pharmaceutics, dyes, and food processing (Chapter 3). Alchemy is the next topic to be taken into consideration by contrasting the approaches to the subject of different cultures such as that of Alexandria, Islam, India, China, and Babylon, and then concentrating on the contributions of Medieval Europe (Chapters 4 and 5). Chapter 6 is dedicated to the 16th century, and specifically to the ways in which the practice of chemistry was reformulated by Paracelsus and the Paracelsians, at the same time it was criticized by their opponents. Chapter 7 deals with the 17th century, taken as the period of independence of chemistry as a science. Special emphasis is placed on van Helmont, Boyle, and Glauber. The 18th century, taken as the period in which chemistry as a rational subject intertwining theory and practice reaches maturity, is addressed in the last three chapters by looking at the problem of affinities, phlogiston theory, pneumatic chemistry, and finally the contributions of Lavoisier.

Two recent books on the history of chemistry come immediately to mind when reading Maar's history of chemistry. They are William Brock's *The Fontana History of Chemistry* (1992) and Bernadette Bensaude-Vincent and Isabelle Stengers' *Histoire de la Chimie* (1995). While they all present overviews of the history of chemistry (or part of it), and therefore share similar scopes, they are driven by very different aims. Brock takes advantage of the many in depth and sophisticated studies which appeared in the last two decades, to counteract the pressure of specialization and offer a new account of the history of chemistry, focusing on its theories and practices as viewed by the best modern scholarship. Bensaude-Vincent and Stengers take a more philosophically oriented approach to the subject to unveil the ways in which the identity of chemistry has been constructed, and the fight for a disciplinary space has taken place throughout the times. Maar presents a history of chemical theories, and facts, extensive but not in-depth, leaving to the reader the task of interpretation. The structure of the book is not innovative, and is definitely inspired by Partington's histories of chemistry, having an almost encyclopedic character. It provides biographies of alchemists and chemists, discusses main theories and technical aspects of alchemy and chemistry, and reports on the 'discovery' and application of chemical substances that are represented in terms of modern notation.

In the preface, Maar outlines the methodology used. Attempting to circumvent a debate which seems to us quite outdated, the author claims to have avoided an entirely internalist perspective without, on the other hand, having succumbed to a strict externalist approach. This middle-ground approach is considered the most adequate because chemists, most of the audience aimed at by the book, are pleased by a narrative based on facts and chemical theories, but on the other hand, as chemistry is a humanist and cultural endeavor, a wider audience, not circumscribed to chemists, should profit from an acquaintance to the history of chemistry. Despite these assumptions, the book is inspired by a positivistic reading of the history of chemistry, and does not avoid a clearly whiggish language and orientation (*e.g.* the author often builds his narrative around lasting contributions, the notion of 'precursors', or a schematization of what he considers to be the methodology of chemistry).

Maar's work is supported by bibliography other than French, British, and American and encompasses literature from Latin America, Portugal, Spain, Russia, Italy, and other 'peripheral' countries. By living in a peripheral country, one can offer a more neutral, uncompromising and open-minded account, so the author claims. The concern to include narrative details outside mainstream literature is certainly Maar's most original contribution, but this enterprise is particularly hard, dependent as it is on bibliographical accounts often opened to criticisms. Even taking into consideration language barriers preventing 'peripheral' literature to be widely disseminated, the production on history of science in peripheral countries is not yet up to international standards, and this is especially striking in the context of Brazil and Portugal. The reasons are manifold. Professionalization has not yet given way to a critical mass of scholars nor to a consistent and regular scholarly production. Often publications use the history of science to serve commemorative purposes as in centenaries, anniversaries, and other celebratory events. And often they do not take into account recent or relevant international bibliography, many times unavailable or available with dramatic delays. This state of affairs has to be acknowledged despite the pride one may feel of belonging to a minority in the international landscape of the history of science. (The author, in fact, acknowledges to his many friends and relatives who throughout the twenty years in which he prepared the book, brought back to Brazil many relevant books and papers).

Regarding this problem, and in view of the aims of this book, it is surprising that Maar refers only to Partington's abridged version, *A Short History of Chemistry* (1989), and ignores his comprehensive 4 volume *A History of Chemistry* (1962-1970). Still in the realm of the general histories of chemistry, the author bypasses the recent contributions by Brock, and Bensaude-Vincent and Stengers. Concerning specific topics, and just to give a few examples: Marie Boas Hall, Steven Shapin and Simon Schaffer, William Newman, or Michael Hunter's contributions on Boyle are not referred to, nor Henry Guerlac, F. Holmes, and Bernadette Bensaude-Vincent's books on Lavoisier. Not even, despite being a work heavily dependent on short biographies, is there a reference to Gillispie's *Dictionary of Scientific Biographies*. In short, bibliographic references are not updated, occasionally going further than the late 1970s, and fundamental books and articles published in English and in French in the last decade, in subjects ranging from alchemy to Lavoisier, are omitted. The same criticisms can be extended to the bibliography from the 'peripheries'. For example there are no references to the extensive Spanish scholarship on the 18^{th} century by scholars such as, to name only a few, António Lafuente, Victor Navarro-Brotons, António Ten, Agusti Nieto-Galan, José Ramon Bertomeu, and António Garcia-Belmar (of which the last three scholars have worked specifically on the history of chemistry).

Considering that there are not many textbooks on the history of science addressed to a Portuguese audience, it seems to us that two alternative ways can be taken out of this situation, which can complement each other rather than being opposed. One is to promote the translation into Portuguese of 'classics' of the discipline as well as recent scholarly contributions, the other the writing of new books and textbooks in Portuguese. In the latter case, one should always take into consideration recent contributions to the academic scholarship in the history of chemistry as well as debates and reflections on historiographical questions.

In view that Maar will address in the sequel to his book the period after Lavoisier, we suggest that he takes again into consideration the contributions to chemistry from people and scientists from peripheral countries. Avoiding the mere enumeration of names and facts, he should profit from new historiographical considerations such as: How have new scientific ideas 'migrated' from centers to peripheral countries? What was the role of different external and internal factors in this 'migratory' process both in global and local scale? What were the specific characteristics of the process of their assimilation? What have been the particular forms of resistance in each country to the new developments? How was the particularity of their expression in each country related to its economic, social, and political life? What were the different profiles and social functions played by 'scientists' in the countries at the periphery? How were the different functions of the 'scientists' related to the different roles played by scientific and technological knowledge in the center and in the periphery? Answers to the former questions will help to characterize the mechanisms of birth and development of the new chemical ideas in the peripheries, and then to assess the similarities and differences of the perceptions of chemistry and chemical technology in different countries.

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Determinants in the Evolution of the European Chemical Industry, 1900-1939. New Technologies, Political Frameworks, Markets and Companies, ed. by A.S. TRAVIS, H.G. SCHRÖTER, E. HOMBURG & P.J.T. MORRIS, Kluwer Academic Publishers, Dordrecht-Boston-London 1998, xii + 393 pp. (ISBN: 0-7923-4890-7)

This book is the outcome of an international conference on the European chemical industry in the first four decades of the 20th century; it includes 16 articles, arranged in five different sections.

The first part deals with a new technology of the 20th century, high pressure industrial chemistry, which was, according to the editors, "nothing less than the 'paradigm shift' that thrust the chemical industry into the 20th century" (p. xii). The article by ANTHONY TRAVIS succinctly presents the development of the high-pressure ammonia synthesis and how high pressure chemistry became the "undisputed leitmotiv of the interwar chemical industry" (p. 21).

Part 2 is devoted to the impact of World War I. ROY MACLEOD describes in detail the "war of chemistry" on both the British and the German side. Scientists of both nations dedicated their knowledge to this deadly business, although their efforts, as MacLeod insists, were not decisive for the outcome of the war. However, their efforts transformed the image of science. LOTHAR MEINZER's article examines the effects of the French occupation of BASF. Referring to the Haber-Bosch process, he convincingly shows that the confiscation of patents was of little use as long as the related contextual, tacit knowledge was lacking. The French had to find agreements with BASF, and the resulting contract between the two parties was, according to Meinzer, "the successful model" of a transnational technology transfer, setting "the pattern for similar activities during the remainder of the interwar period" (p. 63).

Part 3, entitled "Science and Industry", includes two very informative articles on R&D at IG Farben: one is on basic research at IG Farben (CARSTEN REINHARD), the other one on the emergence of heavy organic chemicals in the period 1925-45 (PETER MORRIS). In their introduction the editors write: "The German chemical industry, which was active in R&D even before World War I, turned, for a time at least, to basic questions and fundamental science" (p. xii). Given that the two articles the editors refer to deal only with IG Farben, and more specific with Ludwigshafen, one might question the generalization about "the German chemical industry". Another paper in this part (GEERT SOMSEN) highlights the controversially debated attempts of Dutch academic chemists to gain prestige and money from state and industry. Finally, in the interwar period, they successfully established a national research organization, founding the "Applied Scientific Research".

The fourth part is dedicated to the "different routes to competitive advantage". Three of five articles focus on Great Britain: the modernization of industrial organic chemistry (ANTHONY TRAVIS); the emergence of the profession of chemical engineering (COLIN DIVALL and SEAN JOHNSTON); and reasons for the little use of measuring and controlling instruments in the British chemical industry as compared to the USA (STUART BENNETT). Bennett argues that the craft based British approach "left ownership of knowledge in the hands of the skilled production workers" (p. 235) and that the management was unable to control the tacit knowledge that was passed on in the apprenticeship system. The fourth article is on the Norwegian Hafslung group and its neglect of the Odda process (KNUT SOGNER); the fifth deals with the Swiss pharmaceutical industry and the impact of patent laws on its competitiveness (JAKOB TANNER). Until the late 19th century, Switzerland had no patent law and was considered, with its imitation of products, as a "nation of industrial robber barons" (p. 263). The establishment of a patent law, as demanded particularly by the German industry, benefited the Swiss pharmaceutical companies that focused on highly profitable specialties. Tanner argues, however, that patents were only one side of the protection of knowledge; the other side was tacit knowledge: "Modern industrial enterprises try to protect this codifiable knowledge, which is susceptible to imitation, by means of patenting and secrecy. But the decisive immaterial or intellectual resource for the growth of firms are not patents, brand names, and industrial secrets, which provide temporary advantages, but the tacit knowledge which is strictly specific to every firm and cannot be fully copied by others" (pp. 267-8). This argument leads us back to the high-pressure ammonia process that could not be copied in spite of the capture of patents, because tacit knowledge was indispensable for its working.

The final part is dedicated to state intervention and industrial autarky. ROLF PETRI argues that chemical production in Italy was based on the needs of agriculture and traditional manufacturing until the 1930s. The lack of energy and raw materials apparently prevented the development of a modern organic chemical industry. That changed in the 1930s due to protectionism and the intervention of the Fascist state, accelerating R&D and supporting technology transfer from other countries. NURIA PUIG introduces the reader to the "frustrated rise" of the Spanish chemical industry. HELGHE KRAGH provides an overview of the Danish chemical industry, defining it rather broadly. And TIMO MYLLYNTAUS examines the relatively small Finnish chemical industry in the interwar years.

In conclusion, the book does not supersede the by now thirty years old study of L. F. Haber: *The Chemical Industry 1900-1930. International Growth and Technological Change* (Oxford 1971), which remains the general standard work on the chemical industry for this period. However, the articles in this volume, mostly of good or very good quality, show that there has been made progress since concerning some European countries and particular aspects of the chemical industry. Yet, the field still offers ample opportunities. It may be added that the reviewer was sometimes wondering about the choice of countries represented in this volume – for example, the absence of France. Overall, this is a very stimulating book that presents us important results of research by historians of science and technology and economic historians on the European chemical industry in the first half of the 20th century.

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PAUL RABINOW, *French DNA: Trouble in Purgatory*, University of Chicago Press, Chicago, 1999, viii + 201 pp. (ISBN: 0-226-70150-6)

Paul Rabinow's *French DNA: Trouble in Purgatory* picks up where he left off at the end of his *Making PCR: A Story of Biotechnology* (reviewed in this journal Vol. 4, No. 2). After his study of the Cetus Corporation (which became Roche Molecular Systems), Rabinow was invited by Daniel Cohen to be a "philosophical observer" at CEPH (Centre d'Etude du Polymorphisme Humaine) a partially independent French research group which had ties with the AFM (Association Française contre les Myopathies), a patients organization similar to the American MDA (Muscular Dystrophy Association). Cohen led the CEPH to the first physical map of the human genome in 1993. Financial backing for this project was partially funded by the AFM, which saw that the genetic level was the next battleground in the study of the dystrophies. As there were already sociologists at AFM, Rabinow studied these relationships from the CEPH primarily. Cohen was also a co-founder of an American biotechnology start-up, Millennium Pharmaceuticals. Millennium and CEPH were to start a collaborative effort to work on the genetic basis of diabetes. It is this failed collaboration that prompted Rabinow's book to be an ethnography of failure rather than success.

It is from this failure that the book gets its title. The collaboration was eventually stymied because of genetic material that had been collected from a large number of French families. When one of the scientists, Phillipe Frougel, who was running CEPH's diabetes project, realized that his role in the Millennium collaboration would be very small, he balked, and leaked information to the government and the press. The government, which had already approved the collaboration in principle, reversed itself. The rhetoric was couched in terms of not letting Americans steal and profit from French DNA.

Rabinow's book is a tour-de-force combination of history, sociology, philosophy, and anthropology of science. In his "Introduction", Rabinow sets the stage for his own involvement in the project, particularly the fact that he happened to be there during this "multidimensional crisis in 1994" (p. 4). Chapter 1, "Life as We Know It", introduces the French stance on not paying for blood donations, but instead relying on the virtue of benevolence. It is also in this chapter that Rabinow explains the subtitle of his book, "Trouble in Purgatory". The concept of purgatory in Catholicism arose to take into account new situations. In particular, it was the phenomenon of rich people wanting to get into heaven and a "chronic sense that future is at stake" (p. 17). Rabinow, drawing on the work of historians Jacques Le Goff, Michel Vovelle, Benjamin Nelson, and Michel de Certeau, sees the relationship developing between French research, venture capital, and the virtue of benevolence as another purgatorial compromise – an attempt to find "solidarity and hope" in a difficult time (p. 23).

The history of CEPH and its complicated relationship with the AFM is sketched in Chapter 2, "Genomic Assemblages". Rabinow arrived at CEPH in January 1994, less than a month after the announcement of the completion of the physical map of the human genome. In Chapter 3, "Field Notes: The CEPH after its Victory", he reports on the mood at CEPH, its plans with Millennium Pharmaceuticals, and the other projects underway at the center, fulfilling his role as "philosophical observer". A more difficult discussion takes place in Chapter 4, "Life: Dignity and Value". Here, Rabinow explains the detailed history of the French attitudes and laws about human biological research and how the French decry the role of money in the American way of things (especially paying people for their blood). In the scope of this discussion, he also deals with the history of the monetary, moral, and legal issues raised in the case of the transfusion blood tainted with AIDS in the mid-eighties, as compared to the American handling of the same crisis. The relationship between concepts of 'body' and 'personhood' are difficult to separate.

Chapter 5, "Millennium Comes to Paris", provides an account of the breakdown of the collaboration attempt from February to April 1994, and Chapter 6, "Normalization", explains what happens to the key players in the aftermath of the French DNA crisis. This is followed by an epilogue, "The Anthropological Contemporary", in which Rabinow reflects on his own role in this matter. One issue he addresses in the epilogue is determining what the book is about. One thing he sees is that the book is about competing forms. That is, the different approaches taken by American and French companies, and their governmental and academic counterparts. He had already addressed the changes in the American relationships in *Making PCR*. The competition between these value systems will shape the future of biotechnological research:

> One is for or against abortion, for or against immigration, for or against the commerce in blood, for or against surrogacy, for or against patenting of life forms [...]. Not many people, after all, would respond in an opinion survey that they are against scientific progress, health, dignity, or human rights. However, alongside such a consensus [...] and the divers clusters of practices that seek to embody beliefs lies a more obscured terrain (p. 178).

Further, as with *Making PCR*, he is wary of using 'totalizing' concepts and instead favors more limited concepts. Thus, there can be an epilogue, but no *conclusion*.

French DNA serves as a reminder that the rhetoric of science can mask as it informs, that scientific communication still has a culture barrier even if the language barrier is not as great, and that money is still not the only motivation. We still need to pay close attention to the similarities and differences between what scientists say and what they do. Structures can affect the development of science in ways that are not predictable. *French DNA* is a relatively short book that is very readable and informs as well as provokes. I recommend it to all who would find an anthropology of the contemporary by a 'philosophic observer' to be meaningful. As with *Making PCR*, though, there is no index.

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Pioneering Ideas for the Physical and Chemical Sciences. Josef Loschmidt's Contributions and Modern Developments in Structural Organic Chemistry, Atomistics, and Statistical Mechanics, ed. by W. FLEISCHHACKER & T. SCHÖNFELD, Plenum Press, New York, 1997, pp. 320 (ISBN 0-306-45684-2)

The long subtitle clarifies the scope and aims of the 33 contributions to the volume in honor of Josef Loschmidt (1821-1895), edited by Wilhelm Fleischhacker and Thomas Schönfeld from the Institutes for Pharmaceutical Chemistry and Inorganic Chemistry, respectively, at the University of Vienna. The papers are grouped according to three topics: "Organic Structural Chemistry" (12 papers); "Physics and Physical Chemistry" (14 papers); and finally "Loschmidt's Biography, Loschmidt's World" (7 papers). The declared heterogeneity of research interests ranges over philosophical and historical issues as well as today's experimental and theoretical approaches to molecular reality.

On a commemorative occasion, such diversity is not without danger, but for our purpose it is welcome because the reader may find also a few papers and several passages of interest concerning philosophy of chemistry. Papers and passages may be discussed with reference to two principal topics. Not surprisingly, the first topic regards Loschmidt's own philosophy and the philosophy of science of his times; surprising is rather the shaky quality of many assessments of Loschmidt's place in the history of chemical thought. The second topic regards aspects of the philosophy of chemistry as today's scientists propose it. Many papers could be interesting for an attentive reader because one can see, just under the surface level of the texts, the militant philosophy and applied epistemology of the authors. However, this textual level is implicit, and as such it will remain outside the scope of the present review.

The most promising article on Loschmidt's philosophy is that by PETER M. SCHUSTER, entitled 'From Curiosity to Passion: Loschmidt's Route from Philosophy to Natural Science'. Schuster reports many interesting facts about Loschmidt's early academic interest in Herbart's philosophy, when he was a twenty-year-old student of Franz Exner, professor of Philosophy in Prague. However, since Loschmidt moved to Vienna at the age of 21 to study physics and chemistry, Schuster's claim of a decisive, long lasting influence of Herbart' philosophy on Loschmidt's molecular conceptions seems to me not enough grounded. In the middle of the nineteenth century, the physical and chemical literature was rich of suggestions about the (ontological) relationship between atoms and ether. The concept of atoms as 'spheres of activity' was well-known among physicists and chemists, since it was extensively worked out by Boscovich and (among many others) used by Berthollet (*cf.* H. Kragh: 'The Aether in Late Nineteenth Century Chemistry', *Ambix*, **36** (1989), 49-65). Schuster states that "Loschmidt never gave up Herbart's conceptions of atoms as penetrable orbitals, and interpreted what we call today orbitals as 'ether spheres'" (p. 274).

In a similar anachronistic view, C.R. NOE ('Loschmidt and Venn. Symbolic Logic in Chemistry and Mathematics') claims that Loschmidt's "sphere concept, which was 'off-limits' for organic chemists for a long time [...] can be seen as a forerunner of modern orbital theory" (p. 96). M. JENNER boldly amplifies the same idea ('The Periodic System of the Elements and Prout's Hypothesis. Use and Interpretation by Josef Loschmidt'): "This paper [of 1887] proves Loschmidt to be an early forerunner of the quantum theory, *specifically* of Niels Bohr's famous paper of 1913, in which a theoretical interpretation of the Balmer-lines of hydrogen was obtained (Loschmidt's paper also mentions *specifically* these lines)" (p. 212, italics added). The volume is not lacking in priority claims and extravagant praises, sometime preposterous (*e.g.*, I.D. RAE, p. 121; A. BADER, p. 79). However, at least a couple of contributions provide a more balanced appraisal of Loschmidt's chemical theory (G.P. SCHIEMENZ, 'Spheres from Dalton to Loschmidt. Insights into the Ways of Thinking of a Genius' p. 86), and a more realistic analysis of his perception of the Viennese scientific context (R. ROSNER, 'Organic chemistry in Austria and Loschmidt's ›Chemische Studien‹'p. 117).

As mentioned above, a second thematic area present in the volume is contemporary philosophy of chemistry, as it is proposed in a more or less 'pervasive' form in several papers. Just in the first contribution to the volume, MAX PERUTZ discusses the role of the hydrogen bond and related molecular geometry in physiology, and then explicitly asks the question: "What is the significance of these structures for our conception of *living matter*?" Perutz's answer is that "*Living molecules* [...] combine complexity with a high degree of order which is maintained by a multiplicity of hydrogen bonds and other weak interactions" (pp. 9, 11; italics added).

ALBERT ESCHENMOSER debates the nucleic acid structure problem in terms of chemical etiology in his ample and interesting contribution. Not only does he coherently treat the difficult topic (etiology, as the science of causes), but he also proposes a scheme for elucidating the chemical etiology of nucleic acids that is (almost) explicitly hermeneutic, as is his appraisal of the research: "It is difficult to predict the outcome of such etiological studies, but eventually, and if we are lucky, we might eventually comprehend on a chemical level why the nucleic acids of today are those actually found" (p. 47).

Other points of interest can be found in W.M. HECKL's paper on visualization and nanomanipulation of molecules in the scanning tunnelling microscope technique. One of his issues is: "How would an artist view or paint a molecule? This would be an aesthetic view of a molecule [...]. This is probably not the best method for a chemist, but certainly for somebody interested in art. Such an approach should not be neglected, and we will see later an example of the molecular art, that is a painting done with thousands of molecules" (p. 184). The actual image (fig. 12, p. 189) is reminiscent of the prehistoric cave pictures. Philosophically more promising seems to me his concept of 'quasiepitaxy' that explains the 'visibility' of an absent molecule: "The ultimate limit is the removal of a single molecule of adenine from the surface [...]. The resulting hole can be used to deduce the shape, size and position of a molecule [...]. Single molecule dynamics has been imaged in this case, because the molecular hole was found to change its site, showing diffusion at room temperature". Heckl presents his play with the ghost of a molecule as an example of "molecular nanomanipulation from an artist's point of view" (pp. 188, 190). In VIKTOR GUTMANN's brief and interesting paper 'Considerations about the ›Constitution of the Ether‹', there is a certain (unintentional) connection with Heckl's paper, because here the reader can find many relevant ideas about the separation of an atom or a molecule from the continuum.

The essay of CARL DJERASSI is on a different, more general level of philosophical interest. Its title 'Natural Product Structure Elucidation: 1950 → 2000' suggests a historical narrative, but the author explains the real intentions of the inquiry with a question that deserves to be reported at length: "as the number and power of new physical methods increased, structure elucidation has turned from chemistry into applied spectroscopy and computer-driven X-ray crystallography. What are the costs and rewards associated with these methodological changes and what intellectual and practical motivation now inspires modern natural product chemists?" (p. 15). I leave the task of pondering on the many points touched by Djerassi up to the reader, in particular the epistemological and professional effects of the "irrevocable loss of degradative chemistry in the natural product field" (p. 23). Instead, I conclude this review pointing out a plain and straight consequence of Djerassi's reflections on the disappearance of a relevant number of classical laboratory procedures: the epistemological analysis of these procedures belongs to the history of chemical philosophy rather than to the analysis of the actual way of thinking of contemporary chemists.

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Conference Reports

From the Test-tube to the Autoanalyzer: The Development of Chemical Instrumentation in the Twentieth Century, Workshop of the Commission on the History of Modern Chemistry, Science Museum London, 11-13 August 2000.

Today we are almost surprised that mainstream philosophers of science ignored nearly every aspect of both scientific instruments and experiments until the early 1980s. So, what was that thing called 'science' that they were taking about? First of all, it was an intellectual construction, designed to provide reliable knowledge. Knowledge about what? Those who called themselves 'positivists' or 'empiricists' were concerned about knowledge of sense data provided through the 'naked eye'. They considered basic sensation the most unconditional and decontextualized form of cognition, and as such the most suitable kind for a logical basis or the touchstone of truth. The prize for truth was high, however. It was complete disconnection from all experimental sciences. The 'spectator view' of knowledge, as the pragmatist John Dewey ridiculed it, was a bizarre fiction of science by philosophers.

In the 1920s, the physicist (or physical chemist) Percy W. Bridgman suggested the most radical counter-approach, operationism, that considered experimental operations including instruments, instead of sense data, as the basis of scientific concept formation. Philosophers, who realized that this contextualization undermined the purity of their 'empirical' truth basis, sharply reacted. As Gustav Bergmann put it in the early 50s ('Sense and nonsense in operationism', 1954) in the most absurd manner, experimentation and instrumentation do not add anything fundamentally new – in principle, we could remain spectators and wait until each of the experimental set-ups of science incidentally emerge in nature on their own. By then, mainstream philosophers of 'science' had lost any connection even to experimental physics, as they never had any to chemistry – and what is worse, they did not even realize that.

Strangely enough, it was particle physics, its accelerators and cloud chambers, that became the first object of interest in instrumentation by philosophers of science such as Ian Hacking, Allan Franklin, and Peter Galison in the 1980s. Previous sociological approaches, the so-called laboratory studies of Bruno Latour, Steve Woolgar, and Karin Knorr-Cetina, might have provoked this interest, since they raised severe epistemological questions concerning all philosophies of science that ignore the social context of scientific practice. Philosophers, who were already before forced to give up the strict theory-experience distinction and thereby the 'naked eye' basis of truth, now sought new fundaments in experimental practice, to the effect that there was a boom of the so-called 'new experimentalism' in the late 80s and early 90s. At the same time, also many historians of science gave up their former focus on theories and ideas and started to produce a wealth of in-depth studies on instrumentation, frequently inspired or even co-authored by sociologists and philosophers of science of the new approaches.

From that period is the only corresponding book on chemistry worth mentioning (*The History and Preservation of Chemical Instrumentation*, ed. by J.T. Stock & M.V. Orna, Dordrecht 1986) which is basically a rough stock-taking of recent developments in instrument making and includes some aspects of instrument preservation in science museums. (There is one earlier book that is mainly on US history and less reliable: *A History of Analytical Chemistry*, ed. by H.A. Laitinen, G.W. Ewing, ACS 1977). Despite the two facts that chemical instrumentation goes back to at least as far as Arabic alchemy and influenced 20th century chemistry more than anything else, historians of chemistry have showed extremely little interest in that topic; nor did they feel any ambition to enter the parallel discussions in philosophy and sociology of science. Thus, it is not surprising that the German Chemical Society (GDCh), who annually awards the most prestigious international prize for the history of scientific instruments since 1993, the Paul Bunge Prize of the Hans Jenemann-Foundation, have never found a suitable candidate from the history of chemistry but, for instance, several from the history of astronomy.

Thanks to the recently founded Commission on the History of Modern Chemistry (*cf.* HYLE **5** (1999), 171-4) the odd situation might change in the future because their recent workshop was on "From the Test-tube to the Autoanalyzer: The Development of Chemical Instrumentation in the Twentieth Century", hold at the Science Museum London, 11-13 August 2000. The organizers – PETER MORRIS (Science Museum, London) assisted by CARSTEN REINHARDT (Germany), TONY TRAVIS (Israel), and LUIGI CERRUTI (Italy) – did an excellent job of broadening the focus beyond isolated stories about the invention and making of instruments. Emphasis was rather on the mutual impact between chemical instrumentation, on the one hand, and various aspects and fields of chemistry, neighboring disciplines, chemical industry, technology, politics, economy, and environmental issues, on the other. They also expected stimulation from philosophy, as they invited at least one commentator and two speakers from philosophy of chemistry.

The well-prepared workshop was divided up into four sections with each three pre-circulated papers and two distinguished commentators: "*Different Approaches to the History of Chemical Instrumentation*" (DAVIS BAIRD, USA; JOACHIM SCHUMMER, Germany; TERRY SHINN, France; and commentators ARNOLD THACKRAY, USA; JAMES BENNETT, UK); "*Structures, Spectra, and the Quest for Precision: The Chemical Sciences*" (CHARLOTTE BIGG, UK; CARSTEN REINHARDT, Germany; LEO SLATER, USA; and commentators CARL DJERASSI, USA; DAVID KNIGHT, UK); "*Detection and Control: The Environmental Sciences and the Chemical Industry*" (TONY TRAVIS, Israel; PETER MORRIS, UK; STUART BENNETT, UK; and commentators ERNST HOMBURG, Netherlands; WILLIAM H. BROCK, UK); "*Organisms, Automation, and Innovation: The Biomedical Sciences*" (NICHOLAS RASMUSSEN, Australia; DAVID BROCK, USA; LUIGI CERRUTI, Italy; and commentators CHRISTOPH MEINEL, Germany; PIERRE LASZLO, Belgium/USA).

As it happened, the section 'Different Approaches' was not as different as the organizers might have expected, so that I will regroup the papers and start with TERRY SHINN's. His concept of 'research-technology instrumentation', originally developed in a historical case study on the ultra-centrifuge, combined both methodological and sociological categories to analyze the generation of new devices applicable in diverse fields. Its key features are 'genericity' (general purpose, open-ended design), 'interstitiality' (interdisciplinarity, involvement of various social institutions), and 'metrology' (standardization of units and procedures of measurement). Both CHARLOTTE BIGG and DAVIS BAIRD (more or less intentionally) provided excellent examples of how this concept can help understand the successful development of spectrometers in their case studies on the British company Adam Hilger, Ltd. and the US company Baird Associates, respectively. Furthermore, Stuart Bennett's study on the development of control instruments, with emphasis on their use in the chemical process industry, may be regarded a third example of applying Shinn's concept of research-technology devices.

As another coincidence, both LEO SLATER and JOACHIM SCHUMMER, though from completely different perspectives, suggested that the rapid development and ubiquitous use of spectroscopic methods changed, in view of chemists, the ontological status of molecular structures: from properties to entities. Slater ("Woodward and the Reification of Chemical Structures") referred to natural product chemistry and used biographical material particularly of Woodward. Schummer, in an effort to analyze the impact of spectroscopy on identity concepts in chemistry, referred to synthetic chemistry and applied content analysis of randomly selected paper of the past 100 years. Both came to different results, however, as concerns dating and evaluating the ontological change. The third paper on instrumentation in organic chemistry, was CARSTEN REINHARDT's astute analysis of the development of mass spectroscopy. Originally developed for gross analyses in the petroleum and synthetic rubber industry, mass spectroscopy became one of the most powerful methods of structure elucidation of organic products in the 1960s, and as such superseded the classical chemical methods. However, unlike other spectroscopic methods, this was achieved by applying a chemically oriented approach, *i.e.* by adopting the concepts of reaction mechanism of physical organic chemistry, as Reinhardt pointed out.

Two papers dealt with the impact of chemical instrumentation on environmental analysis. TONY TRAVIS reviewed the rapid instrumental improvements of quantitative spectroscopic analysis of synthetic organic compounds and trace metals since the 1930s, illustrated by the tremendous shift of detection limits from the ppm to the ppt range. As his main thesis, he argued that the driving force of improving instrumental techniques for environmental analysis and monitoring was the control of laboratory conditions and manufacturing processes within the chemical industry. In a sense complementary was PETER MORRIS' study of the development of the electron capture detector and its application in environmental analysis. On the one hand, he gave a biographic account of its inventor, James Lovelock, one of the most unconventional physical chemists who was incidentally also the inventor of the Gaya thesis. On the other hand, he placed the improvement of detection methods in the context of both the competition with bioassay methods and the medical as well as political question of threshold values. As chemical detection levels are now frequently below politically fixed threshold values, Morris concluded that chemists have done their job. Nonetheless, I think the issue seems to be worth further sociological investigation as to how chemical instrumentation has impact on the public awareness and assessment of environmental issues.

The final section, on chemical instrumentation in the biomedical sciences, consisted of three papers, each exploring disciplinary boundaries with different philosophical implications. DAVID C. BROCK analyzed the origin, development, and marketing of chemical autoanalyzers in the clinic, as a continuation of Foucault's social history of medicine. He argued that the clinic was the birthplace of the autoanalyzer and remained the center of its technological evolution until at least the 1970s. This in turn changed the clinical practice fundamentally, from classical pathology to biochemical 'chart analysis' in which blood values rather than human bodies are subject to therapy. In his study on chromatographic and electrophoretic techniques, LUIGI CERRUTI first showed how these methods were crucial to the development of biochemistry, particularly to protein biochemistry, since they allowed for the first time the isolation of many compounds to be followed by biochemical reasoning on the structure-function relationship. In his second part, he provided many examples of how this biochemical approach was mixed and combined with classical biological approaches, originating new hybrid disciplines such as molecular evolution. NICLAS RASMUSSEN's study on the bioassay as an biochemical instrument, while being full of historical details, essentially presented an interesting antireductionist argument that I would reformulate in the following manner. Insofar as biochemical properties are operationally defined by means of bioassays, and thus necessarily depend on concepts of biological functionality, they cannot be reduced to chemical properties alone as long as the concepts of biological functionality are not redefined in terms of chemical properties.

Overall, the workshop took place in a very stimulating atmosphere, supplemented by Peter Morris's circumspect care of all the participants' needs. Given the previous lack of interest in the topic, a great deal of work of gathering historical material was necessary and much is still to be done. The way in which the material was placed in topics of general interest, *i.e.* the mutual relation between instrumentation and various scientific and non-scientific fields, should be continued and further enlarged. Having been both a philosophical participant and 'observer', I may suggest that philosophy of technology and philosophy of chemistry should even be more considered as complementing and inspiring future historical research. As to the former, clarification and diversification of concepts such as 'instruments' or 'tools' in terms of purposes inside and outside of science might be helpful to systematize the material and to draw more precise conclusions. As to the latter, I am pleased to say that there is now a growing number of philosophers of chemistry who are interested in instrumentation and could further enrich the discussion.

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Wilhelm Ostwald at the Crossroads of Chemistry, Philosophy, and Media Culture, University of Leipzig, 2-4 November 2000.

When Ostwald received the Nobel Prize of chemistry for his work on catalysis in 1909, he had already retired 3 years ago, at the age of 53, from his chair of physical chemistry at the University of Leipzig. How did this most influential co-founder of the new physical chemistry spend his remaining 26 years at his private estate near Leipzig, after having educated some 100 later professors of physical chemistry worldwide; and why did he finished his successful university career at all?

Nicely located at the University of Leipzig, an international workshop organized by philosopher of chemistry Nikos Psarros and historian of chemistry Britta Görs, shed new light on widely unknown facets of a great chemist. To start with the final discussion, the number of papers (16) did not suffice to cover all his manifold activities. Besides Ostwald the physical, analytical, and technical chemists, the founder and editor of chemistry journals and book series, the tireless chemistry textbook writer and historian of chemistry, there was also Ostwald the quick-witted philosopher, the ardent reformer and leader of various international movements, the enthusiastic popularizer of science, as well as the painter and poet who tried to apply the aesthetic theories on which he had been working so hard during his final 20 years.

Did all these activities spring up from his chemistry? Not directly. It rather emerged from philosophical reflections on chemistry. Ostwald himself was quick in elaborating his views towards an abundant and complex philosophy of nature that incorporated even sociology, psychology, ethics, and aesthetics. Though he received harsh criticism from many of his scientific colleagues, his philosophy was throughout scientistic, an all-embracing scientific world view, largely based on three principles: an experimentalist epistemology; the metaphysical priority of energy over matter; and the strongest belief in societal progress by means of science, technology, and social organization. Since for Ostwald progress meant working against the consequences of the 2nd law of thermodynamics, his general demand became: "Do not waste energy – ennoble it!" As a direct consequence, he retired in order to engage in pressing organizational matters, *i.e.* in more efficient 'energy flows and transformations' for societal progress, such as educational reforms and international information and documentation management, or standardization of 'media', such as of paper format, an international artificial language, and even money. Moreover, Ostwald considered both war and traditional religion as 'unscientific' waste of energy, to the effect that he became a leading figure in both the World Peace Movement and the Monist League, the latter being an atheistic, science-based quasi-religion.

Fortunately, there was ample time for discussion during the workshop, for with each paper presenting a new puzzling facet of Ostwald his personality became more and more difficult to comprehend. As a working hypothesis, Anders Lundgreen (Uppsala University) suggested Ostwald's deeply rooted pursuit of unity and harmony, ranging from his earlier attempts at unifying chemistry and physics to his final theoretical and experimental work on color theory and aesthetics. On the other hand, many papers revealed strong ambiguities, even contradictions within Ostwald's views, such as between modernism and anti-modernism, internationalism and nationalism, anti-metaphysics and metaphysics *etc*. There was agreement that Ostwald, the restless writer who first used a phonograph as dictaphone in order to save time and energy, took up many ideas from others and changed his topic and mind too frequently to allow a consistent reading of his entire work. While this has given rise to many misunderstandings since, he nonetheless became probably the intellectually most influential chemist of the 20th century.

Besides his autobiography and the memoir of his daughter Grete, there is only an early Russian biography of Ostwald worth mentioning (by Rodnyi & Solowjew, 1969; trans. into German 1977). Recent attempts of the Ostwald archive to edit his 10,000 letters as well as the proceedings of this workshop will make the long overdue new biography both more easy and more difficult to write.

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