Materials in Eighteenth-Century Science: A Historical Ontology by Ursula Klein and Wolfgang Lefèvre

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Reviewed by
Georgette Taylor
University College London
g.taylor@ucl.ac.uk

Perhaps the first thing to be said about this book is that it is not advisable to try to read it in a library, or indeed to read any other copy than one's own. Librarians (and friends) tend to frown on readers who scrawl 'YES' or large tick marks and arrows in the margin, or who disturb reading rooms with cries of enthusiasm. This book elicited all these reactions from me, so consider yourselves warned. The book sits firmly in the canon of scholarly works on the history of chemistry, as might indeed have been expected from these authors; and it should form part of the library of all who consider themselves historians of chemistry of whatever period. It offers an example of a new and exciting way of 'doing' history of chemistry, judiciously mixing sound historical study with what I would like to call analytical history and a good dose of philosophy of science. The methodology will be partly familiar to anyone who knows Ursula Klein's previous work, as indeed will some of the book's themes, but the drawing together of ideas stemming from over 10 years of research into this book length study extends their scope tenfold.

Broadly, the book offers a historical study of the changing ontological status of materials (substances) in the chemistry of the 18th and 19th centuries. But beyond this, it also explores the very nature of the chemical substance: where such entities originate, how they are constituted and, once individuated and identified, how they are classified. The notion of substance has been insufficiently studied in the past by historians, and philosophers of science have tended to approach the question from a somewhat metaphysical point of view. This work instead examines the science of materials, chemistry, in the 18th and 19th centuries when a concept of substance that we might

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recognize was initially formed. Rather than taking that somewhat overused route into the study of any science, the study of its sociological networks, this work is clearly intended to be about the science itself. Although it is concerned to emphasize the artisanal origins and medical/pharmaceutical roles of the substances which form the work's focus, all these are delineated through the practices and concepts that chemists adopted in order to understand such substances. This is a book about science in history, not scientists in history; and it is all the better for it. Similarly, the authors have chosen not to adopt the usual present-centered focus on systems of ultimate elements or particles, but instead to look at 'the most significant scientific objects of classical chemistry—chemical substances' [9]. The book thus examines a level of theorization that differs from more metaphysical philosophical systems, instead dealing with questions relating to the material, perceptible world: how substances interact and how they can be ordered and related to each other. This kind of theory has recently begun to be recognized and explored by historians of chemistry and, in particular, by those who have examined the doctrine of affinity that was so prevalent in 18th century chemistry [see, e.g., Kim 2003]. Nevertheless, the epistemological status of this level of theory has not so far been explored thoroughly. Klein and Lefèvre argue that this kind of theorization originated in the early years of the 18th century with the new conceptualization of the combination of pure chemical substances to form compounds and their corresponding analysis. As the authors show here too, classification systems also encapsulated ideas about the materials studied by chemists and thus offer access to this level of theorization about material substances.

The book is divided into three parts with 16 chapters bookended by an introduction and conclusion. It is extremely densely written—there is a huge amount of information contained in every line; nay in every phrase. Those who have read Ursula Klein's previous publications will know that her work is difficult to paraphrase simply because it is so thickly textured. This is not a book for merely dipping into; it must be read from end to end. Although each of the three parts can stand alone, each chapter is carefully structured so as to build on the work done by the previous one, and the journey taken by the reader as he follows the authors' arguments through each part is not one that could be taken by short cut.

The first part of the work is occupied with a discussion of the historical and philosophical status of the materials and substances studied by chemists and characterizes their various approaches to the study of these bodies. It also sets the work itself in its own historiographical and philosophical context. The latter is important, as the work as a whole, and particularly part 1, is deeply informed by philosophy of science as well as by history, referencing (and often disagreeing with) philosophers such as Foucault, Hacking, Bachelard, Rheinberg, Pickstone, Putnam, and, of course, the omnipresent Kuhn. What becomes clear is that although philosophers have explored a variety of scientific objects through studies of taxonomies and theories of reference as well as through scientific approaches to the notion of substance, they have rarely, if ever, approached either topic from a chemical point of view. Klein and Lefèvre seek in this work to rectify this omission by focusing their attention on the objects of chemical enquiry, the substances themselves, as 'multidimensional objects of enquiry'. They show that, beginning in the 17th century, 'academic chemists' studied materials in a variety of different ways: as applicable, useful materials; as perceptible objects with perceptible properties; and as carriers of imperceptible features.

The authors have seized here on a whole domain of practices that have so far been relatively unexplored. They seek both to define this domain—an act for which I think future historians of chemistry will have cause to be grateful—and to explore the activities and practices that characterize it. The domain they describe lay between (and often overlapped with) the two often denominated 'natural history' and 'experimental philosophy'. The first of these tended to involve the observation, description, and ordering of natural objects and phenomena, while the second entailed the experimental investigation of the imperceptible entities that underlay the visible world with the aid of a variety of philosophical instruments. The third domain described by Klein and Lefèvre (which they call, after Bacon, 'experimental history') was concerned with the collecting and ordering of facts relating to 'the perceptible dimension' of phenomena obtained by the intervention in nature. This Boyleian style of investigation was deliberately free from speculation and connected closely with artisanal activities and practices. This, together with technological improvement and experimental philosophy, describes the three

different styles of experimentation and observation adopted by 18th century chemists in their studies of materials.

Klein and Lefèvre are also concerned to expose the strong material connection between early modern chemistry and the practices of artisans and craftsmen. As they point out, historians of chemistry have not previously shown much interest in the provenance of the substances that appear in chemists' laboratories. For the authors this is an important omission. Substances did not arrive in the laboratory with a clean slate; they had a past and chemists' approaches to them were in part colored by that past. Most of the substances studied by 18th century chemists were commodities, products of artisanal processes; many were imported from foreign lands and used in manufacture of a variety of goods. These substances, they argue, were boundary objects, linking academic chemists with apothecaries, metallurgists, mineralogists, assayers, and so forth; but they were also multidimensional objects of inquiry with different aspects that were studied in different ways. However, they also argue that as chemists studied and investigated substances, so these substances began to be changed:

> Materials were... transformed when they became objects of inquiry for academic chemists. Chemists invested them with new meaning, and sometimes even transformed their boundaries by splitting them into different kinds of substances. New individuations and identifications of substances—such as the division of air into different kinds of air—went hand in hand with material transformations. [19]

This book sets out to explore the patterns of such changes from the 17th into the 19th centuries; but rather than exploring these 'shifting ontologies' through a focus on specific substances or materials and the changes in their ontological status, the authors have chosen to take a broader, more general view. Classification systems, they say, reflect chemists' understandings of the materials with which they work, providing access to

> what kinds of objects were handled in scientific practices of the past, how historical actors conceived of these objects, and how they selected and highlighted those of their manifold features they considered significant. [9]

Classification systems also govern the division of the historical part of the book into two separate parts, the first [part 2] covering the predominantly mineral substances that Klein and Lefèvre denominate 'pure chemical substances', while the second [part 3] examines the taxonomies applied to vegetable, later 'organic' substances. The notion of 'pure chemical substances' will be familiar to those who have read Klein's early works on affinity tables [1994, 1995, 1996] and here she builds on those studies very effectively. The authors point to a new concept that emerged at the beginning of the 18th century that established a 'conceptual network' linking 'concepts of chemical compounds, separation or analysis, recomposition or synthesis, and affinity in new ways' [48]. This new network of concepts underpinned the tacit demarcation of 'pure chemical substances' as those substances which could be combined together to form compound substances and then reliably be recovered from such combinations (by the informed manipulation of the affinities between substances) from those substances (like the majority of plant and animal substances) which, once decomposed, were not resynthesizable. The authors' examination of chemists' classification of this relatively small group of substances shows that it was in this class of substances that what can (perhaps a little whiggishly) be recognized as a modern concept of analysis became evident in chemical practice. From the first few decades of the 18th century, these substances were identified, individuated, ordered, and classed on the basis of their composition; and as Klein and Lefèvre show, both the pre-revolutionary affinity tables and the revolutionary *Tableau de nomenclature chimique* adopt the same taxonomical structure based on composition.

This comparison of pre- and post-revolutionary taxonomies has obvious implications for the historiography of the chemical revolution. Conventionally seen as a rupture, in Kuhnian terms a revolution, they show that although the new chemistry did indeed instigate nomenclatural reforms, these were built on a presupposed classification that had been tacitly used for these 'pure chemical substances' since the early years of the century. Taking Kuhn's own pointer as a guide to incommensurability, they perform an astonishingly deep analysis of the assumptions and logic that underpinned the *Tableau de nomenclature chimique* as it appeared in the 1787 *Méthode de nomenclature chimique*, a work that many have argued was the manifesto of the new chemistry. They compare the taxonomic structure

evinced by the *Tableau* with that of the tables of affinity that had proliferated since the middle of the 18th century, showing that 'the kinds of the one system are directly translatable into the kinds of the other' [185]. Where other historians have sought to map particular substances pre- and post- chemical revolution, and have encountered problems of reference and translation, Klein and Lefèvre seek instead to map taxonomical categories represented in the tables of affinity onto the categories represented in the *Tableau*. They therefore offer a new approach to the vexed question of whether phlogiston can be mapped onto a single substantial entity of the anti-phlogistonist taxonomy in a consistent and coherent way. In this regard they claim that phlogiston was *the phlogistic counterpart* [180] of oxygen and *calorique*. This claim seems to be based on the operations and processes in which phlogiston was combined with or separated from other pure chemical substances—the resulting classes of compound substances are shown to be a mirror image of those formed by the addition or removal of oxygen or caloric. This is why the practices associated with blowpipe analysis remained essentially unchanged before and after the chemical revolution; the addition or removal of phlogiston from mineral substances that formed the basis of this kind of analysis was achieved by the same practices that added or removed oxygen, albeit in reverse. The classes of phenomena produced were also the same in pre- and post revolutionary blowpipe analysis.[1] The authors characterize the classification change that took place during the chemical revolution as 'not the result of a change of the mode of classification but rather a change in the existing mode of classification' [67]. There was, therefore, 'no ontological rupture'. Thus, they succeed in putting flesh on the bones of the nagging doubt (to mix metaphors somewhat) which must be familiar to most historians of 18th century chemistry that pre- and post-revolutionary chemistry were not, in taxonomic terms at least, incommensurable. The significant changes that they pick out occurred instead in the early years of the 18th century as the new network of concepts of compound, analysis, and affinity emerged and in the 1830s, when a compositional or constitutional approach to the classification of what by now were called 'organic' substances became feasible.

[1] The author gave a paper exploring this point at the Annual Conference of the British Society for the History of Science at Manchester in 2007.

The work demonstrates clearly how much historians can gain from a close, even a micro-reading of certain texts. Tables are logical structures, built on complexes of assumptions and encapsulating a network of theories and ideas. The kind of analysis carried out by Klein and Lefèvre in part 2 offers an example of how such a structure can be logically analyzed to glean valuable information about the compilers' understanding of the bodies being ordered. This is almost a combination of history and science in action, and it is an example that historians can learn a great deal from. Historians of science have always wrestled with the problem of how to gain access to the most fundamental assumptions that underpinned the practice of science. These assumptions and beliefs are, for the most part, so basic that they remain unarticulated. The analysis of logical structures like tables can, as Klein and Lefèvre show in this work, offer a way to gain information on the kinds of tacitly held beliefs that is only rarely perceptible from more conventional texts.[2]

Much of part 3 will be largely familiar to readers who have encountered Klein's recent papers on the classification of plant substances [2005a, 2005b]. This part of the work focuses on chemists' attempts at ordering, individuating, and classifying plant substances, most of which were excluded from the class of 'pure chemical substances'. These substances could not be reliably manipulated, and as the authors show, they were ordered and classified throughout the 18th and well into the 19th centuries on the traditional basis of perceptible properties. As they also make clear though, this is not to say either that analysis was not carried out on these kinds of substances, nor that the taxonomy of these materials was static. Their study indicates that analysis was indeed carried out on plant substances but that this was a different kind of analysis in terms of its objective, methods, and meaning. Prior to the middle of the 18th century, the term 'analysis' was only rarely used with regard to plant substances; and in the few cases when it was mentioned, it was used to indicate the acquisition of knowledge in a theoretical rather than experimental context. From the mid-18th century though, the authors point to the increased emphasis on, and study of, the relatively compound, 'proximate principles' of plants which, they argue, was driven in part

[2] A similar kind of logical analysis can be found of the assumptions that underlay affinity tables in Taylor 2006, ch. 5.

by the focus on composition prevailing in the study of the pure chemical substances. These proximate principles became the substances that were identified, ordered, and classified as plant substances, although the mode of their ordering remained the traditional one of perceptible properties. It was only in the 1830s, as the authors very briefly show, with the work of Dumas and Boullay that a similar mode of classification on the basis of a binary composition could be instituted for what were now known as 'organic' substances. Where part 2 demonstrated that the ontology of pure chemical substances remained surprisingly unchanged in a deep sense throughout the 18th and into the 19th century, part 3 shows that although the mode of classification of plant substances remained similarly static throughout the period under consideration, the broader demarcation of what were originally denominated plant substances but later became organized bodies and eventually organic substances, shifted regularly. Throughout the period, what was considered as one class or species of plant substance changed, and substances were included or excluded as the ontologies shifted. These shifts cannot be described as revolutionary or as ruptures, but they did reflect deep changes in the conceptualization of substances emanating from the vegetable realm.

This part in particular emphasizes a number of subtly distinct processes that were necessary (but not sufficient) conditions of the creation of a chemical classification. One such process is the demarcation of the substances to be classified from those that, for example, were of the wrong ontological order or had originated in the wrong place or had been submitted to the wrong processes or were groups rather than individuals. Part 2 explored the demarcation of the 'pure chemical substances' from other bodies, but part 3 points to a number of shifts in the groups of substances that were classed as 'plant substances' or 'proximate principles of plants' or finally as 'organic substances'. Beyond this there is the difficulty of individuation. This is a problem rarely considered by historians or philosophers of science, but which lies at the heart of many of the ontological shifts described by the authors. How did the chemist decide that the substance with which he was dealing was just one homogeneous substance? Once again, in part 2 the authors showed how this problem was dealt with in regard to pure chemical substances, where the homogeneity of each substance was built into the initial classification system. The contrast with the messy and often incoherent individuation of

plant substances is clear. Further beyond still is the more familiar philosophical problem of identification; connected to the problem of individuation, this was again a key concern for chemists of both the 18th and 19th centuries. As plant materials could not be decomposed and resynthesized in the same way as the pure chemical substances could, all these classification processes were much more problematic when applied to vegetable substances.

This book is important for the history of chemistry in so many ways. It sets a historiographical, methodological, and philosophical example for historians of science in general as well as historians of chemistry. It demonstrates the advantages that can accrue to both history and philosophy of science by adopting an approach that is becoming known as 'integrated history and philosophy of science'.[3] The historical case studies which make up the heart of this work are thoroughly informed by philosophy of science, and indeed many of the questions being asked by the authors originate in that discipline. At the same time, the historical study and, in particular, the analysis of the taxonomical structures of chemistry are seen to offer answers to these questions which in turn must color our acceptance of a number of philosophical generalizations. History of chemistry has to date been somewhat under-utilized for historical case studies; and, as the authors show, such historical studies have much to offer to philosophers of science. The authors use their own historical investigations to show that, so far as chemistry of the 18th and 19th centuries is concerned, neither Foucault's epistemes, Bachelard's rupture, nor Kuhn's revolution provide appropriate models.

Their study also demonstrates how the history of chemistry can be brought into the 21st century, while leaving most of the present-centeredness of our century behind. Debunking a number of myths that have been too long propagated by historians of chemistry in thrall to the atom- and element-obsessed present, this book emphasizes the materiality of chemistry, and the role of tangible, sensible, physically manifest substances, the objects of study of chemists of the 18th and early 19th century. The authors avowedly state in their introduction that their intention is not to follow the conventional route of histories of chemistry, focusing on particles, Newtonian forces, and eventually atoms. Nor indeed do they spend much time on systems

[3] See Chang 2004, particularly the introduction and chapter 6.

of elements or principles, at least no more time than did their protagonists. This is a new direction for the history of chemistry (although Klein's earlier work has already led us a little way down this path) and it is to be wholeheartedly welcomed. Their work fulfills a long outstanding desideratum by focusing instead on the materials, the substances, with their tangible and not so tangible properties such as color, taste, smell, acidity, alkalinity, medicinal value, solubility, inflammability, and so on. This was, of course, how most chemists looked on the substances with which they worked, and for too long historians have chosen to ignore this fact in order to concentrate on speculative hypotheses of particles, atoms, and primitive principles. Such hypotheses were present throughout the 18th and into the 19th century, of course; but, as Klein and Lefèvre show, from the middle of the 18th century, in terms of what the majority of chemists actually did, they were far less relevant than the classificatory structures that chemists adopted. Even though most chemical textbooks paid lip service to one or other such elementary system, this seems to have been dictated more by convention than by actual chemical practice. Klein and Lefèvre emphasize that in spite of the elementary rhetoric, most chemists were in fact more concerned with the proximate principles or pure chemical substances that they could get by analysis (whether in the modern sense or in the older, less familiar sense), and with which they could make new substances. Accordingly, it is with the endeavors to identify and classify those substances that were subject to this order of ontological decomposition and recompounding that they concern themselves in this book. Klein and Lefèvre's work offers an example to today's historians of chemistry of how their discipline can be enhanced by adopting not only their actors' categories, but also their chemical concerns.

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