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The *Méthode de nomenclature chimique* (1787): A Document of Transition

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The *Méthode de nomenclature chimique*, published by the *Académie Royale des Sciences* in 1787, is rightly praised as a landmark in the history of early modern chemistry. It is also – though less rightly – considered to be a fruit of Lavoisier's Chemical Revolution. In fact, main features of the *Méthode*'s nomenclatural and classificatory proposal rest on fundamental chemical conceptions that were shared by adherents of the phlogistic chemical system as well. After a short presentation of the *Méthode*'s four authors (Berthollet, Fourcroy, Guyton de Morveau, and Lavoisier) and the circumstances of their collaboration, my paper will focus on those features of the *Méthode* that illuminate decisive achievements of the entire community of eighteenth-century chemists, as well as those features that reveal an unsettled state of many of its convictions.

In 1787, four prominent French chemists – Louis Bernard Guyton de Morveau, Antoine-Laurent Lavoisier, Claude Louis Berthollet, and Antoine François Fourcroy – published a book with the title *Méthode de nomenclature chimique*.¹ In this book they proposed a new nomenclature of chemical substances, explicated their principles of methodically constructing chemical names, and further presented a taxonomic table of chemical substances. Historians of chemistry have unanimously praised the *Méthode* as a key document of eighteenth-century chemistry, and

¹ Louis Bernard Guyton de Morveau, Antoine-Laurent Lavoisier, et al., *Méthode de nomenclature chimique. On y a joint un nouveau système de caractères chimiques, adaptés à cette nomenclature, par M.M. Hassenfratz et Adet* (Paris: Cuchet, 1787). For bibliographical information on French editions as well as contemporary translations of this book, see Ferdinando Abbri and Marco Beretta, “Bibliography of the ‘Méthode de nomenclature chimique’ and of the ‘Traité élémentaire de chimie’ and their European Translations (1787–1800),” in *Lavoisier in European Context: Negotiating a New Language for Chemistry*, ed. Bernadette Bensaude-Vincent and Ferdinando Abbri (Canton, MA: Watson Publishing International, 1995), 279–91.

particularly of Lavoisier's epoch.² Since the nomenclatural and the taxonomic proposals of the *Méthode* were constructed in accordance with Lavoisier's antiphlogistic chemical system, most historians have regarded it as a fruit and manifestation of this chemical system, and some of them have even portrayed it as a clever device for its propagation.

In what follows, I outline a somewhat different view of the *Méthode*, one that does not interpret it primarily as one of the acts in the drama of the so-called Chemical Revolution, and one that particularly departs from the classic story that conceives of this Revolution as the *telos* of eighteenth-century chemistry.³ Instead, I will focus on features of the *Méthode* that exhibit a new conceptual foundation characteristic not just of Lavoisier's chemical system, but of chemical theories accepted by the vast majority of chemists in the second half of the eighteenth century, constituting a conceptual foundation shared by phlogistonists and antiphlogistonists alike.⁴ This new conceptual understanding testified not only to advances achieved by these chemists, but also, as will become clear, to traits of older conceptual assumptions that they had not discarded completely. The *Méthode*'s proposals furthermore expose significant limitations of the chemistry of Lavoisier's time that were removed only in the nineteenth century. But we begin first with the circumstances of this book's origin and publication.

² For assessments and discussions of the *Méthode*, see Wilda Anderson, *Between the Library and the Laboratory: The Language of Chemistry in Eighteenth-Century France* (Baltimore: Johns Hopkins University Press, 1984); Bernadette Bensaude-Vincent, *À propos de 'Méthode de nomenclature chimique': Esquisse historique suivie du texte de 1787* (Cahiers d'Histoire et de Philosophie des Sciences 6, Paris: Centre National de la Recherche Scientifique, 1983); Bernadette Bensaude-Vincent, "Un charte fondatrice: Introduction," in *Guyton de Morveau, Lavoisier, Berthollet, Fourcroy: 'Méthode de nomenclature chimique'* (Paris: Éditions du Seuil, 1994), 9–60; Bernadette Bensaude-Vincent, "Introductory Essay: A Geographical History of Eighteenth-Century Chemistry," in Bensaude-Vincent and Abbri, eds., *Lavoisier in European Context*, 1–17; Marco Beretta, *The Enlightenment of Matter: The Definition of Chemistry from Agricola to Lavoisier* (Canton, MA: Watson Publishing International, 1993), chap. 4; Marco Beretta, "The Grammar of Matter: Chemical Nomenclature during the 18th Century," in *Sciences et langues en Europe*, ed. Roger Chartier and Pietro Corsi (Luxembourg: Office for Official Publications of the European Communities, 2000), 109–25; Maurice Crosland, *Historical Studies in the Language of Chemistry* (London: Heinemann, 1962), part III; François Dagognet, *Tableaux et langages de la chimie* (Paris: Éditions du Seuil, 1969), part I; Jan Golinski, "The Chemical Revolution and the Politics of Language," *The Eighteenth Century: Theory and Interpretation* 33 (1992): 238–51; Ursula Klein and Wolfgang Lefèvre, *Materials in Eighteenth-Century Science: A Historical Ontology* (Cambridge, MA: MIT Press, 2007), part II; Jessica Riskin, "Rival Idioms for a Revolutionized Science and Republican Citizenry," *Isis* 89 (1998): 203–32; Lissa Roberts, "Setting the Table: The Disciplinary Development of Eighteenth-Century Chemistry as Read through the Changing Structures of its Tables," in *The Literary Structure of Scientific Argument: Historical Studies*, ed. Peter Dear (Philadelphia: University of Pennsylvania Press, 1992), 99–132; Robert Siegfried, "Authority and Authorship in the Method of Chemical Nomenclature," *Ambix* 49 (2002): 206–26; and William A. Smeaton, "The Contributions of P.-J. Macquer, T. O. Bergman, and L. B. Guyton de Morveau to the Reform of Chemical Nomenclature," *Annals of Science* 10 (1954): 87–106. This selection of secondary literature could easily be extended if one drew in literature on the four authors of the *Méthode* or on the Chemical Revolution in general, much of which addresses the nomenclatural enterprise of 1787.

³ For critical assessments of this classic story, see for instance Frederic L. Holmes, *Eighteenth-Century Chemistry as an Investigative Enterprise* (Berkeley, CA: Office for History of Science and Technology, Univ. of California, 1989), part V, and, more recently, Matthew D. Eddy, Seymour H. Mauskopf, and William R. Newman, "An Introduction to Chemical Knowledge in the Early Modern World," *Osiris* 29 (2014): 1–18, on 6n.

⁴ "Except at those strategic points at which the theoretical structure of the new chemistry impinged upon it ... the new nomenclature was not revolutionary, but the continuation of an evolutionary movement made necessary by the very success of pre-Lavoisier chemistry in expanding the number of substances requiring names"; Holmes, *Eighteenth-Century Chemistry*, 15.

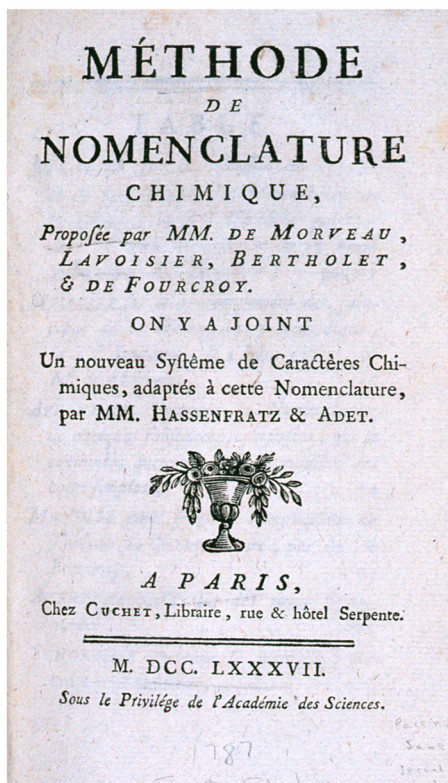


FIGURE 1 Original title page of the *Méthode de nomenclature chimique* (1787).

“Sous le Privilège de l’Académie des Science”

The *Méthode de nomenclature chimique* was published “sous le Privilège de l’Académie des Sciences,” as the title page announces (Figure 1).⁵ As such, it was a kind of official document of the Parisian Academy, containing the nomenclatural proposal submitted by the four authors to the Academy in spring 1787 along with a report by four members of the Academy in charge of the proposal’s evaluation.⁶ Although the tone of this evaluation was reserved rather than enthusiastic, the four authors of the book had achieved their immediate goal: their nomenclatural proposal was issued as a document of the Parisian Academy.⁷ And indeed, this proposal was in

⁵ For a more elaborate account of the *Méthode*’s origin and publication, see Klein and Lefèvre, *Materials in Eighteenth-Century Science*, chap. 4.

⁶ The evaluators were Antoine Baumé, Antoine-Alexis Cadet de Vaux, Jean D’Arcet, and Balthazar Georges Sage. Baumé and Sage made their reservations public after the *Méthode*’s appearance; see Crosland, *Language of Chemistry*, 185.

⁷ A “privilege” accorded to a publication by the Académie des Sciences testified that the publication had gone through the Academy’s standard procedure of discussion and evaluation; it did not testify to the Academy’s approval of the content of the publication. The report of the four evaluators, which, by the way, expressed doubts regarding Lavoisier’s antiphlogistic chemical system but did not criticize the proposed method of naming and classifying chemical substances, ends accordingly by saying: “... que nous croyons que le tableau de nomenclature nouvelle de chimie, avec les mémoires qui sont joints peuvent être imprimés & rendus publics sous le privilège de l’Académie,

need of a protective shield, for not only did it have to reckon with the resistance that radical nomenclatural reform proposals always meet; it furthermore contained a chemical nomenclature that conformed to Lavoisier's antiphlogistic chemical system. As this system was hardly generally accepted at the time, the proposal was bound to provoke the majority of chemists. It therefore seems quite natural that some historians believed that the chief aim of the *Méthode* was indeed the propagation of Lavoisier's new chemistry. Two facts support this assumption. The first is that in the late 1780s the four authors of the *Méthode* can be, and actually were, regarded as "the antiphlogistic task force," as Henry Guerlac put it.⁸ Second, there is the striking fact that, except for Guyton de Morveau, none of the authors had previously studied the state of chemical nomenclature in systematic detail and elaborated a proposal for its reform. As we will see below, however, there are also a number of facts that point to a quite different purpose of the *Méthode*.

To begin with Claude Louis Berthollet (1748–1822), there is no evidence that he had previously shown any special interest in nomenclatural issues. Moreover, his contribution to the *Méthode* remains unrecognisable. Perhaps his name appeared on its title page primarily because he was the first chemist of note to accept Lavoisier's antiphlogistic chemical system. This was in 1785.⁹

Antoine François Fourcroy (1755–1809), the youngest of the four authors, had shown some casual concern for the suitability of particular chemical names, without engaging nomenclature in a systematic manner.¹⁰ In 1786 he announced his acceptance of Lavoisier's system in a special introduction to his *Éléments d'histoire naturelle et de chimie*, which due to its great popularity became a main vehicle for Lavoisier's new chemistry. Since his contribution to the *Méthode* included a detailed explanation of its taxonomic table, one may assume that he assisted Guyton de Morveau in constructing this table.

Antoine-Laurent Lavoisier (1743–1794) had been well aware of the importance of a suitable chemical nomenclature since early in his chemical

⁷ *Continued*

de manière pourtant qu'on ne puisse pas en inférer qu'elle adopte ou qu'elle rejette la nouvelle théorie" (Guyton de Morveau et al., *Méthode*, 131f.)

⁸ Henry Guerlac, "Antoine-Laurent Lavoisier," in *Dictionary of Scientific Biography* (hereafter DSB), vol. 8 (New York: Scribners, 1981), 80.

⁹ On Berthollet, see James R. Partington, *A History of Chemistry*, 4 vols. (London: Macmillan 1961–70), 3: 496–534; S. C. Kapoor, "Claude Louis Berthollet," DSB, vol. 2 (1970), 73–82; and Michelle Sadoun-Goupil, *Le chimiste Claude-Louis Berthollet: Sa vie, son oeuvre* (Paris: Vrin, 1977). Trained as a physician and instructed in chemistry by Pierre Joseph Macquer and Jean Baptiste Michel Bucquet, Berthollet had not only been an adherent of the phlogistic chemical system well into the 1780s, but also an acute critic of Lavoisier's new ideas. Furthermore, when he finally convinced himself of the correctness of Lavoisier's experiments, he did not accept Lavoisier's theories *in toto*. In particular, he opposed Lavoisier's understanding of acids.

¹⁰ On Fourcroy, see Georges Kersaint, *Antoine François de Fourcroy, sa vie et son oeuvre* (Paris: Museum Nationale d'Histoire Naturelle, 1966); William A. Smeaton, *Fourcroy: Chemist and Revolutionary, 1755–1809* (Cambridge: Heffer, 1962); Partington, *History of Chemistry*, 3: 535–66; and Smeaton, "A. F. de Fourcroy," DSB, vol. 5 (1981), 89–93. Similarly to Berthollet, Fourcroy was introduced to chemistry by Macquer and Bucquet as a medical student, and started lecturing on chemistry in the latter's private laboratory. He succeeded Macquer in the important chair of chemistry at the Jardin du Roi. By the time he joined the other three authors in the nomenclatural enterprise he enjoyed high repute as a chemist, particularly through his well-attended lectures.

career.¹¹ In his work on gases he was forced several times to invent names for newly identified gases, and was confronted with neologisms proposed by other chemists. There is also no doubt that his interest in the logic of constructing names predates Guyton de Morveau's suggestions for a new chemical nomenclature.¹² However, there are no indications that he himself had thought of a systematic and exhaustive reform of chemical nomenclature before Guyton de Morveau travelled to Paris early in 1787 to consult with Lavoisier, Berthollet, and Fourcroy on the problems of the nomenclatural project he had been pursuing since the early 1780s.

Finally, Louis Bernard Guyton de Morveau (1737–1816), perhaps the least known of the four authors at the time, was a lawyer by training, and served as one of the public prosecutors and members of the parliament in Dijon, his native city.¹³ He started in chemistry as an autodidact amateur, but soon attained significance through his efforts to promote chemistry in Dijon and more broadly in Burgundy. In 1780 he became known to the community of French chemists, as he was commissioned to write the chemical volumes of the *Encyclopédie méthodique*. In pursuit of this systematic work, he increasingly felt the need for a radical reform of chemical nomenclature. As early as 1782 he published a well-received *Mémoire* on this subject.¹⁴ Although well acquainted with Lavoisier's chemistry since meeting him for the first time in 1775, he remained an adherent of the phlogistic chemical system until his visit to Paris in 1787. There, finally, he adopted the new doctrine that made it possible to commence the collective work on a new nomenclature.

It thus appears that two intentions drove the creation of the *Méthode*: the intent to promote the new chemistry – this may have been Lavoisier's concern in particular – and the intent to replace a chemical nomenclature that had developed over centuries without any rules, by one that was methodically constructed – this was doubtless Guyton de Morveau's main concern.¹⁵

¹¹ See Crosland, *Language of Chemistry*, 168ff. There is a large literature on Lavoisier. See esp. Guerlac, *Antoine-Laurent Lavoisier*; Partington, *History of Chemistry*, 3: 363–94; Jean Pierre Poirier, *Lavoisier – Chemist, Biologist, Economist* (Philadelphia: University of Pennsylvania Press, 1993); Bernadette Bensaude-Vincent, *Lavoisier: Mémoires d'une révolution* (Paris: Flammarion, 1993); and Arthur Donovan, *Antoine Lavoisier: Science, Administration, and Revolution* (Cambridge: Cambridge University Press, 1996).

¹² Lavoisier had realized the potential of Condillac's *Logique* (1780) for methodically constructing chemical names immediately in the very year of this book's appearance: see William R. Albury, "The Logic of Condillac and the Structure of French Chemical and Biological Theory, 1780–1801," PhD thesis, Johns Hopkins University, 1972; Guerlac, "Lavoisier," 81; and Beretta, *Enlightenment of Matter*.

¹³ On Guyton de Morveau, see Partington, *History of Chemistry*, 3: 516–19; W. A. Smeaton, "L. B. Guyton de Morveau," *DSB*, 5 (1981), 600–04; Georges Bouchard, *Chimiste et conventionnel* (Paris: Perrin, 1938); William A. Smeaton, "L.B. Guyton de Morveau (1737–1816): A Bibliographical Study," *Ambix* 6 (1957): 18–34; Claude Viel, "Guyton-Morveau, père de la nomenclature chimique," in *Lavoisier et la révolution chimique*, ed. Michelle Goupil (Paris: SABIX, 1992), 129–70; and *A Scientific Correspondence during the Chemical Revolution: Louis-Bernard Guyton de Morveau and Richard Kirwan, 1782–1802*, ed. Emmanuel Grison, Michelle Goupil and Patrice Bret (Berkeley, CA: Office for History of Science and Technology, University of California, Berkeley, 1995).

¹⁴ Louis Bernard Guyton de Morveau, "Mémoire sur les dénominations chimiques, la nécessité d'en perfectionner le système et les règles pour y parvenir," *Observations sur la physique* 19 (1782): 370–82.

¹⁵ For the history of chemical nomenclatures, see Crosland, *Language of Chemistry*. Up until the end of the eighteenth century, chemists used names of chemical substances that highlighted a variety of the substances' features: their provenance (e.g. *vitriol of Chypre* – copper sulphate); their perceptible properties (*sucré de Saturne* – lead acetate) and chemical behaviour (*alkali minérale effervescent* – sodium carbonate); their uses (*sel febrifuge de Sylvius* – potassium

As already indicated, the four authors' linking of the proposed new nomenclature to Lavoisier's new chemical system was a bold challenge to the chemical community. However, it is important to see that Lavoisier and his collaborators had only two choices in the given situation: either to risk such a partisan proposal, or to postpone their nomenclatural project altogether to an indefinite future. If the new names were to indicate the composition of substances, and if adherents and opponents of the phlogistic chemical system did not agree upon the substances' composition, then they often could not agree upon the names. This concerned not only the names of the newly identified gases (for instance, should the so-called "vital air" be denominated Priestley's "dephlogisticated air," or Lavoisier's "oxygène"?). It also concerned the names of long-known substances such as the metal calces (as metal oxides had been called before Lavoisier). It was precisely this difficult and delicate situation that impelled Guyton de Morveau – still an adherent of the phlogistic chemical system at the time – to travel to Paris for consultation with Lavoisier and his group on how to pursue a reform of chemical nomenclature.

A "tremendous success"¹⁶

Against this background, it comes as no surprise that the nomenclature proposed by Lavoisier and his collaborators did meet with resistance and a variety of objections.¹⁷ A main objection concerned of course the intimate connection of the new nomenclature to Lavoisier's antiphlogistic chemical system. It was argued (by Henry Cavendish and many others) that as many different chemical nomenclatures as chemical systems would unavoidably be the result if the nomenclature did not remain strictly neutral towards different chemical theories held at the time. Others voiced a similar qualm regarding the very principle of naming chemical substances according to their composition, since knowledge of composition might change over time. Some critics (among them Jean Claude de la Métherie, the sternest French opponent of Lavoisier) pointed to the danger that the new nomenclature would create a divide between the chemical language of scientists and that of chemical practitioners such as pharmacists, dyers, or metallurgists. And there were also special as well as general linguistic objections, in particular in connection with translations of the *Méthode's* nomenclature into different vernaculars.

In light of these objections, it may seem surprising that the new nomenclature was by and large accepted within fifteen or twenty years in almost all European countries

¹⁵ *Continued*

chlorate); their methods of preparation (*précipité rouge* – mercuric oxide); or their discoverers or creators (*alkaest de van Helmont* – aqueous solution of potassium carbonate). Moreover, since distinctions and identifications of chemical substances developed over time, many substances had been assigned several names, while a single name sometimes designated different substances. Under such conditions, it was a matter of chance whether names indicated relations among chemical substances in a way that was meaningful for a knowledgeable chemist.

¹⁶ "Reactions to the publication of the *Méthode de nomenclature chimique* were immediate, and most of them were negative. But despite the hostile initial reception, the fierce discussion aroused by the new nomenclature contributed to its steady spread and its eventual tremendous success" (Beretta, *Enlightenment of Matter*, 221f.).

¹⁷ In this paragraph, I follow Crosland, *Language of Chemistry*, 177–214.

as well as in the United States. The various chemical nomenclatures that emerged in different vernacular languages around 1800 were to a large degree uniform, since they followed the same model, that of the nomenclature of the *Méthode* of 1787.¹⁸

How was it possible that the proposed nomenclature was so rapidly adopted? It is a remarkable circumstance that even adherents of the phlogistic chemical system made use of it, which suggests that chemists used the new nomenclature without feeling forced to accept Lavoisier's antiphlogistic chemical system. A ready hypothesis to explain such widespread flexibility might be that the new nomenclature had practical advantages that were obvious to all. Systematically constructed names of chemical substances can easily be memorised when they follow a general rule. This is an important point in particular with respect to teaching chemistry. Such names facilitate communication, and furthermore allow assigning new names to hitherto unknown substances that are immediately intelligible within the community of chemists.

However, as plausible as this explanation appears, the new nomenclature's surprising success may well be due to additional and indeed more fundamental reasons. I argue that two issues above all must be considered here: first, the appeal of a classification of substances underlying the new nomenclature; and second, a shared, conceptual deep structure of the phlogistic and the antiphlogistic chemical systems. As we have argued in detail elsewhere, Lavoisier's revolution was not a conceptual rupture, but rather a major revision within the existing framework of this conceptual deep structure.¹⁹ Ursula Klein has termed this deep structure the "conceptual network of chemical compound and affinity."²⁰ Let us further examine this question.

Nomenclature and classification

The new names the four authors gave to a certain range of chemical substances were designed to convey these substances' composition – in particular, according to their antiphlogistic understanding of these substances' composition. But more than a theory of composition was needed for the nomenclatural project they pursued. Such an enterprise was possible only by means of a systematic classification of the substances that were to be renamed. If a name had to clearly and unambiguously designate just one particular chemical species *A*, and at the same time provide information about its composition, relations had to be established between the species *A*

¹⁸ On the spread of the new nomenclature in Europe, besides Crosland's *Language of Chemistry*, see also Bernadette Bensauade-Vincent and Ferdinando Abbri, *Lavoisier in European Context*. The process of the *Méthode*'s adoption exhibits a well-known generational feature: young chemists were the first who made use of the new nomenclature, whereas well-established figures took the path of refusal or reluctance. This situation is aptly illuminated by a remark made by Joseph Priestley, an adherent of the phlogistic chemical system until his death: "... whether [we] adopt the new system or not, we are under the necessity to learn the new language, if we would understand some of the most valuable of modern publications" (quoted in Crosland, *Language of Chemistry*, 198).

¹⁹ Klein and Lefèvre, *Materials in Eighteenth-Century Science*, particularly chap. 10; and Ursula Klein, "A Revolution that Never Happened," *Studies in History and Philosophy of Science (A)* 49 (2015): 80–90.

²⁰ Klein and Lefèvre, *Materials in Eighteenth-Century Science*, 56–58.

and the species *B*, *C*, *D* ... (and their compositions) of which *A* was composed. In order to establish such a web of relations a systematic classification according to composition was required. This is exactly what the four authors provided. They based their nomenclature upon a classification of the chemical substances to be renamed – a classification constructed for this purpose and included in the *Méthode* in the form of a table. (The principal features of this table will be discussed below.)

The *Méthode*'s taxonomic table presents the first taxonomic system of chemical substances in history that classifies consistently according to the composition of substances. It is therefore rightly regarded as a landmark in the history of chemistry.²¹ Thus, the systematic character of the *Méthode*'s nomenclatural proposal resulted not only from a required employment of certain linguistic rules, but was also due to a methodically constructed classification provided by the four authors.²² As I will show below, this classificatory proposal was attractive not only to followers of Lavoisier's antiphlogistic chemical system, but to others as well.

A shared conceptual deep structure

The taxonomic table and the nomenclature of the *Méthode* are confined to "elements" – or what were then taken to be "simple substances" – and inorganic compounds.²³ As a consequence, the *Méthode* excluded the bulk of substances that chemists dealt with at the time, particularly almost all plant and animal materials that were of the highest significance for pharmacy, medicine, and other fields of application. Why did the authors not strive for a comprehensive classification of all chemical substances known at that time? And why did they focus just on this selection of substances?

The substances in the focus of the enterprise of our four authors formed a special group that had a long history. They had been assembled into such a special group since the end of the seventeenth century. The core of this group included metals, metal oxides, and alloys on the one hand, and acids, alkalis, earths, and salts on the other. As Ursula Klein has shown, these two clusters of chemical substances originated in two fields of practical chemistry – metallurgical chemistry as practised in connection with mining, and the manufacturing of salts as practised in apothecary

²¹ For classifications of inorganic compounds before 1787, see Klein and Lefèvre, *Materials in Eighteenth-Century Science*, chap. 9. Classifying chemical substances according to their composition might seem quite natural, but this was not, and is not, natural at all. Other modes of classifying chemical substances – such as those summarized in n. 15 above – have been employed over centuries and are still alive in technological contexts.

²² For these linguistic rules and their dependency on Condillac's linguistically designed *Logique*, see Lavoisier's *Mémoire* in the *Méthode* (Guyton de Morveau et al., *Méthode de nomenclature chimique*, 3ff.); see also Klein and Lefèvre, *Materials in Eighteenth-Century Science*, 187ff.

²³ The term "element" is deliberately avoided in the following, for two reasons. First, the authors of the *Méthode* themselves left open the question of whether the substances in the table's column for simple substances were true chemical elements, or merely apparently simple substances that had so far resisted every attempt to decompose them. Second, the avoidance of the term "element" will allow us to trace fundamental conceptual structures of the table back to seventeenth- and early eighteenth-century chemistry, where the terms "element," or "simple principle," had entirely different meanings.

shops.²⁴ And as she has further shown, academic chemists united these two clusters into one special group of chemical substances around 1700, due to the experience that the substances comprised in these clusters equally lent themselves to “reversible” chemical operations, that is, compositions and subsequent decompositions into the original ingredients. Mostly by way of displacement reactions in which a third substance was superadded in the molten state, alloys could be decomposed into their metallic components, and resynthesized out of them. Likewise, salts could be decomposed into acids and salifiable bases, and resynthesized out of them.

We have unmistakable evidence for the long history of this special group of substances and the interplay of practical and theoretical chemistry that singled it out: the famous tables of chemical affinity.²⁵ The first of these tables was the “Table des différents rapports entre différentes substances” constructed by Étienne François Geoffroy (1672–1731) and published as early as 1718 (Figure 2).²⁶

What was emerging in this way is the core of a conceptual deep structure that was shared by adherents as well as critics of the phlogistic chemical system: the (early) modern concept of a chemical compound, and a pragmatic and relativistic notion of more simple substances from which these compounds are made. Since this understanding is familiar to the modern reader, one may not immediately see what is new here. The novelty becomes visible, however, against the old understanding of “elements” and “mixts” (*mixta*) that coexisted with the new conceptual system well into the eighteenth century. Let me briefly outline this viewpoint.

A new ontology

According to the new understanding that emerged in the decades around 1700, chemical compounds were composed of simpler substances, building blocks, as it were, tied together by elective chemical affinities. Chemists identified these building blocks as chemical substances that could be both isolated and manipulated experimentally to recompose the respective chemical compound. According to this viewpoint, there was no ontological difference between a compound and its components:

²⁴ See Ursula Klein, *Verbindung und Affinität: Die Grundlegung der neuzeitlichen Chemie an der Wende vom 17. zum 18. Jahrhundert* (Basel: Birkhäuser, 1994), part VI, and Klein and Lefèvre, *Materials in Eighteenth-Century Science*, chap. 2.

²⁵ For these affinity tables, see Alistair M. Duncan, *Laws and Order in Eighteenth-Century Chemistry* (Oxford: Clarendon Press, 1996).

²⁶ See Étienne François Geoffroy, “Table des différents rapports observés en Chimie entre différentes substances,” *Histoire de l’Académie Royale des Sciences: Avec les mémoires de mathématique et physique pour la même année* (1718): 202–12 and Geoffroy, “Table of the Different Relations Observed in Chemistry between Different Substances – 27 August 1718,” *Science in Context* 9 (1996), Special Issue: Fundamental Concepts of Early Modern Chemistry, ed. by Wolfgang Lefèvre: 313–19. The first comprehensive interpretation of this table was presented by Ursula Klein, “E. F. Geoffroy’s Table of Different ‘Rapports’ Observed between Different Chemical Substances – A Reinterpretation,” *Ambix* 42 (1995): 79–100. Affinity tables listed tested or assumed elective attractions between chemical substances, and thus reversible decompositions and re-compositions of compounds. Since these tables were not connected with any specific theory of affinity (Geoffroy himself, as many other eighteenth-century chemists after him, did not develop such a theory), one has to distinguish between these tables on the one hand, and, on the other hand, concepts of affinity proposed by some chemists (e.g. Torbern Bergman). See Holmes, *Eighteenth-Century Chemistry*, 109, and Maurice Crosland: “[Review of] U. Klein and W. Lefèvre: *Materials in Eighteenth-Century Science. A Historical Ontology*,” *Annals of Science* 66 (2009): 421–22.

Mém. de L'Acad. 1764. Pl. 8. pag. 212

TABLE DES DIFFERENTS RAPPORTS
observés entre différentes substances.

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FIGURE 2 Geoffroy's *Table des différents rapports* (1718).

both were considered to be ordinary chemical substances. This constitutes a major difference from “components” such as atoms, Aristotelian “elements,” or Paracelsian “principles” that were defined in the long philosophical tradition. In the new system, the simplicity of the building blocks and the compounded nature of chemical substances were defined on the base of experimental knowledge about the various possibilities of their decomposition, hence in a relative way and not as an absolute property of these entities.

In contrast, according to the alchemical doctrine that was predominant in the early modern period, that is, according to Paracelsianism, the components of ordinary substances were conceived as “elements” and “principles,” which did not belong to the world of ordinary substances. Ordered into an ontological hierarchy of matter, they belonged to an ontological level that generated the ordinary substances. They were conceptualised as generators of, rather than physical components of, the *mixta* that were the perceptible substances that chemists dealt with in their laboratories.

It is important not to mistake *mixta* with our mixtures. *Mixta* were homogeneous substances that received their “form” or specificity from the “elements” or “principles.” *Mixta* were understood to be marked or determined by, but not to consist of, “elements” or “principles,” if “to consist of” means to be composed of pre-formed building blocks that are ordinary and manipulable substances that could

be separated and isolated by chemical art. Furthermore, Paracelsians understood all *mixta* to be constituted by the same three (later five) universal “principles.”²⁷ *Mixta* differed, therefore, not in terms of the set of “principles” that constituted them, but in terms of the proportions or different states of equilibrium, or domination, between the constituents.

Viewed against this background, the early modern conception of chemical compound that underlies and predates our four authors’ classification according to composition signals a fundamental change in chemists’ understanding of the realm of chemical substances. This change amounts to a true ontological shift. The new conception presupposed that all substances chemists worked with belonged, without exception, to the same ontological level. The former hierarchical ontology was transformed into a “flat” ontology.²⁸ This fundamental transformation of the very notion of a chemical substance took place in a slow process beginning in the second half of the seventeenth century, a process which exhibits, in hindsight, many inconsistencies, and which was hardly complete at the time the *Méthode* appeared. Moreover, this transformation took place almost tacitly, that is, almost without explicit discussions of its philosophical implications.

The slowness of the process, together with the fact that it took place without explicit theoretical discussions, constitute reasons why this change of the deep structure of chemists’ understanding of chemical substances, which amounts to no less than the emergence of the bedrock of modern chemistry, has been nearly overlooked by historians of chemistry before Ursula Klein’s work. In addition, the novelty of the “conceptual network of compound and affinity,” as she termed it, was overlooked because of its modernity. Since it appears as correct in principle, it has been taken more or less for granted, and some historians of alchemy and chemistry do not believe that chemists had ever thought differently.

Phlogiston

This new, modern conceptual understanding of chemical substances and their reactions united adherents and opponents of Lavoisier’s chemical system. It was not the result of but rather the basis for Lavoisier’s achievements. But what does it mean that adherents of the phlogistic chemical system also shared this conceptual basis? Must we conclude that even phlogiston fits in this new conception?²⁹ This idea may at first appear strange, since phlogiston’s function for certain properties of substances such as combustibility and colour suggests an ontological character analogous to that of the Aristotelian elements or the Paracelsian principles, rather than to that of ordinary chemical substances.

²⁷ Sulphur, mercury, and salt had been the original Paracelsian principles, to which *phlegma* (water) and *earth* were added in the course of the seventeenth century.

²⁸ See Klein, *A Revolution that Never Happened*, section 2.2.

²⁹ For the following, see Klein, *A Revolution that Never Happened*, section 2.4.

Whereas substances such as metals, acids, and salts were known in artisanal as well as alchemical practices, phlogiston did indeed arise in a theoretical context, namely in the context of the Paracelsian philosophy of principles and mixts discussed above. However, Georg Ernst Stahl's theory of combustion conceptualised phlogiston as participating in reversible operations like an ordinary component of a chemical compound. In a similar vein, in 1718 Geoffroy included phlogiston in his affinity table under the name "principe huileux ou soufre principe."³⁰ In doing so, Geoffroy allotted to it the ontological status of an ordinary laboratory substance. Most subsequent affinity tables followed his example.

Regarding the 1785 affinity table of the Swedish chemist Torbern Bergman, the most elaborated of all such tables, a curious fact deserves attention in our context.³¹ Among other new substances that had been identified in the course of the eighteenth century as exhibiting elective affinities, Bergman included "vital air" (oxygen) as a reference substance in his table, without removing phlogiston. This was taken as redundant by the English chemist William Nicholson, who skipped the column of Bergman's table that contained vital air as a reference substance, remarking: "... in the anti-phlogistic theory, the column entitled Phlogiston being taken in the reverse order, will express the elective attraction of Vital Air."³² Nicholson thus implicitly demonstrated that, by simple inversions, proven orders of affinities could be preserved from becoming dependent on a decision for or against the phlogistic or the antiphlogistic chemical system. There can be no doubt that the historical actors fully understood what their opponents were talking about. They did not live in different chemical worlds.³³

Thus, on the basis of their shared understanding of chemical substances and their reactions, late eighteenth-century chemists understood phlogiston as a substance that could be separated and handled as a building block of compounds for the production of chemical compounds. The fact that it remained a hypothetical substance that could not be isolated was not a decisive handicap in their eyes. As we will see, some of Lavoisier's simple substances were such hypothetical substances as well. It was the shared conceptual understanding of chemical substances and their reactions that made the classification and nomenclature proposed by Lavoisier and his collaborators acceptable in principle for adherents of the phlogistic chemical system,

³⁰ By designating it "principe huileux ou soufre principe," Geoffroy pointed back not only to Paracelsus' "Sulphur," but also to experiments with ordinary sulphur that were taken as demonstrating that phlogiston was involved in its decomposition and re-composition.

³¹ Torbern Bergman, *A Dissertation on Elective Attractions [= De attractionibus electivis disquisitio 1775]*, transl. by T. Beddoes (London: J. Murray 1785).

³² Quoted in Duncan, *Laws and Order*, 166.

³³ For adherents of the phlogistic chemical system in later times, the shared conceptual and ontological background of the phlogistic and antiphlogistic theories becomes even more manifest. Some of these late phlogistonists accepted a part of Lavoisier's theory of oxidation, and conceded that oxygen played a role in combustion. Priestley and Heinrich Klaproth even agreed with Lavoisier that oxygen caused the increase in weight of the combustible. But they also argued that phlogiston was simultaneously released from the latter. In so doing, they reasoned regarding chemical composition and affinities in the same way as Lavoisier had. See Klein, *A Revolution that Never Happened*, section 2.4.

especially since they could adapt them to their own system by simple transformations on paper.

Mirror images

Which of its features made the *Méthode*'s classification plausible for adherents of the phlogistic chemical system as well as for Lavoisier's followers, and how could the former adapt it to their own system by appropriate transformations? In order to answer this question, we must outline the structure of the *Méthode*'s taxonomic table.³⁴

Despite its restriction to inorganic substances, the table is crowded with an enormous number of names.³⁵ Thus, it would take some time to recognise structures and patterns. We can abbreviate this recognition process by means of a diagram that clarifies the table's classes of substances and their arrangement (Figure 3).

The table consists of six vertical columns juxtaposed horizontally. Each of the columns is divided vertically into fields that represent actually existing or possible classes of chemical substances. Two columns (II and V) contain only one actual class; the other columns contain two, three (if field III/a is taken as a class), or even five classes. Thus, we find fourteen (or thirteen) actual classes in the table, which are distributed into six higher taxonomic units. Two of the columns, namely column II and the upper part of column IV, contain classes of gaseous substances. The two classes of gaseous substances comprise compounds of the matter of heat (*calorique*), with either simple substances (II/a, b, and e) or with oxygenated substances (IV/b), also known as acids.

The first feature of the classificatory structure that must be stressed is the exceptional position of column I. Whereas the five other columns, without exception, contain classes of substances regarded by the authors of the *Méthode* as compounds, column I comprises only classes of substances that they took to be simple substances. It contains five such classes: first, a class comprising four substances that are unknown today and were then regarded as coming very close to the absolute state of simplicity,³⁶ namely the matter of light (*lumière*), the matter of heat (*calorique*), *oxygène*, and *hydrogène* (the latter two must not be mistaken for our oxygen and hydrogen); second, a class of the "acidifiable bases," e.g. sulphur, charcoal, and phosphorus; third, the class of the metals, semi-metals included; fourth, the class of the earths; and fifth, the class of the alkalis. In eighteenth-century chemistry,

³⁴ For an exhaustive analysis of the classification of chemical substances that underlay the *Méthode*'s nomenclature, see Klein and Lefèvre, *Materials in Eighteenth-Century Science*, part II.

³⁵ Notwithstanding this enormous number of names, the authors of the table did not claim to list all of the appertaining substances in each of the classes of compounds. Completeness was not their aim, "mais" – in Fourcroy's words – "de réunir sous plusieurs classes de composés un assez grand nombre d'exemples choisis, pour qu'on pût, à l'aide d'une étude simple & facile, appliquer notre méthode de nommer à tous les composés que les chimistes connaissent, ou à ceux qui peuvent être découverts par la suite" (Guyton de Morveau et al., *Méthode de nomenclature chimique*, 76). At the bottom of the table is an appendix with a few organic substances, which we will ignore here. For this appendix, see Klein and Lefèvre, *Materials in Eighteenth-Century Science*, 255–56.

³⁶ "Substances qui se rapprochent le plus de l'état de simplicité" (Guyton de Morveau et al., *Méthode de nomenclature chimique*, 30).

	I	II	III	IV	V	VI
	Classes of Simple Substances	I + Matter of Heat	I + Oxygen	III + Matter of Heat/Others	III + I/d-e and III/b + III/c	I + I
a	Simplest Substances	Gases	Water			
b	S, C, P ...		Acids	Gaseous Acids	Neutral Salts	Compounds of S, C, P
c	Metals		Metal Oxides	Compounds of Metal Oxides		Alloys
d	Earths					
e	Alkalis					

FIGURE 3 Classificatory structure of the *Méthode*'s taxonomic table.

the last three classes of column I constituted a particular taxonomic unit, that of the so-called bases of neutral salts. As for metals, the authors of the *Méthode* followed Torbern Bergman and regarded, not the metals, but metal oxides (field III/c) as "salifiable bases."

Columns II through V are for classes of compounds, of which the classes of compounds in one and the same column are classes of analogous substances.

Column III comprises three classes: a possible class that contains only one substance, namely water, and two actual classes, namely acids and metal oxides. The authors of the table assumed that these classes of substances were analogous because they considered all of them to be oxides. Here we encounter a main source of conflict between adherents and opponents of the phlogistic chemical system. These factions differed over the question whether these classes were analogous because all of the relevant substances resulted from the removal of phlogiston by combustion (as the adherents of phlogiston claimed), or from the combination with oxygen (as their opponents argued). We will come back to this important pair of analogous classes below.

In column V we encounter the realm of neutral or middle salts; that is, of salts that eighteenth-century chemists considered to be combinations of acids with one of the

salifiable bases – namely, metals or metal oxides, earths, and alkalis. Consequently, the column contains only one class that by and large corresponds to the class of acids in column III.³⁷

Finally, column VI comprises two classes of combinations of simple substances that are “in their natural state, without being oxidized or acidified,”³⁸ that is, combinations of simple substances that do not involve oxygen. The first class, which corresponds to the class of acidifiable bases in column I, contains combinations of sulphur, carbon, and phosphorus with metals or alkalis. The second class, which corresponds to the class of metals in column I, contains alloys and amalgams. Compounds of sulphur and alkalis with metal oxides (or what Lavoisier regarded as such oxides) are placed in the lower half of column IV – a placement that has the appearance of a dilemma, as this column was dedicated to classes of gaseous compounds.

The next feature of the classificatory structure that must be particularly highlighted is the table’s arrangement of the taxonomic units in the manner of a matrix. Because of this layout, all of the genera and species are related in a twofold way to other units of the same rank. Vertically, they are related to those taxonomic units that are of the same genus – either the genus of simple substances (column I) or one of the five genera of compounds (columns II–VI). Horizontally, if they are simple substances, the species are related to the compounds of which they are components. Or, if they are compound substances, they are related to one of their components, and at the same time to other compounds of this component. Thus, the table contains two different but coordinated classificatory systems: vertically, a system that distributes classes of substances into either the genus of simple substances or into one of the five genera of compounds, and horizontally, one that arranges compounds according to one simple substance that these compounds have in common.

The horizontal structure of the table deserves particular attention, for it is this particular structure to which the nomenclature of the table is immediately linked. Each horizontal line of a simple substance and its compounds is rendered as a linguistic line of derivations developed from the simple substance’s name, as shown in the following example: Soufre (I) – Acide sulfurique/sulfureux (III) – Gaz acide sulfureux (IV) – Sulfate/Sulfite de potasse (V) – Sulfure de fer (VI).

The invention and application of such linguistic lines presupposed classes of substances that were already distributed into five principal types of compounds (column II–VI). If one asks why the authors of the *Méthode* chose these particular five principal types of compounds rather than others, one encounters a further stratum of the chemical framework of the table’s classification. Superimposed upon its general component–compound structure, there is an additional structure of classification,

³⁷ The few salts formed with a metal oxide instead of an acid (field IV/c) obviously did not induce the authors of the table to introduce a separate class.

³⁸ “...substances simples combinées dans leur état naturel, & sans être oxigénées ou acidifiées...” (Guyton de Morveau et al., *Méthode de nomenclature chimique*, 97).

	I	II	III I/b + Oxygen	IV	V III + I/d-e and III/b + III/c	VI
a	Oxygen					
b	Acidifiable Bases		Acids		Neutral Salts	
c			Metal Oxides			
d	Earths					
e	Alkalis					

FIGURE 4 Web of classes linked and organised by the conception of neutral salts.

constructed with respect to the understanding of three particular chemical syntheses: the synthesis of neutral salts, the synthesis of alloys, and the synthesis of gases.

The conception of neutral salts linked the classes of salifiable bases with the class of acids, which class, for its part, was linked with the class of acidifiable bases, and furthermore with oxygen. The concept of neutral salts thus immediately connected the three classes of salifiable bases (columns I/d, e and III/c) with the class of acids (III/b); and, mediated by the latter, it also connected all of these classes with the class of acidifiable bases (I/b) and with oxygen (Figure 4). Considering the extent to which the table's classificatory structure depended on the conception of neutral salts, this conception proves to be the central web of this structure.

Two further webs of classes can be recognised. First, there is a web of two classes of gaseous substances (fields II/a, b, and e taken as one class, and field IV/b), linked by Lavoisier's conception of compounds of the matter of heat (*calorique*). And second, there is the web of classes of metals, metal oxides, and alloys (field I/c, III/c, and VI/c). The classificatory weight of this web of classes resulted from the domain of chemistry it represents, the field of metallurgy.

Having determined which kinds of syntheses should structure the classificatory table – the conception of neutral salts including that of acids, the conception of compounds of *calorique*, and the conception of metallic oxides and alloys – the authors of the *Méthode* had to find a unifying and consistent taxonomic arrangement for the different clusters of classes resulting from the selected syntheses. For this purpose, they looked for classes of compounds that pertain to different clusters of classes, but are analogous with respect to composition. They found two such classes: the

acids and the metal oxides. Both classes comprised substances that were thought to be combinations of simple substances with oxygen, but pertained to different clusters of classes. More precisely, both classes pertained to the cluster around the neutral salts; the class of metal oxides was at the same time also part of the cluster built around the metals. This had important consequences. It allowed the authors to link the two most important webs of classes by uniting these webs' classes of simple substances in column I, and incorporating their two analogous classes of compounds into column III, the column of compounds of simple substances with oxygen. The result of this linkage was the classificatory system given by columns I, III, V, and VI – except for the field VI/b (Figure 3).³⁹

Let us now come back to our initial question – how could the *Méthode*'s classification appear plausible for adherents of the phlogistic chemical system as well as for Lavoisier's followers? Based on the analysis of the classificatory structure of the table above, the answer to this question is simple:⁴⁰ the table's main classificatory structure was not a novelty. Its backbone, the linkage of the cluster of classes around the conception of neutral salts with the cluster of classes around the conception of metal oxides and alloys, can be traced back to the beginning of the eighteenth century, as Geoffroy's table of affinities from 1718 testifies. By implication, these two clusters of classes themselves were far from being inventions of the authors of the *Méthode*.

Furthermore, upon closer inspection, some of the table's seemingly novel classes prove to be antiphlogistic mirror images of classes already distinguished and constructed in the frame of the phlogistic chemical system. The class of acidifiable bases (I/b) can be taken as an antiphlogistic mirror image of the sulphur genus in the traditional class of inflammable mineral bodies.⁴¹ The sulphur genus comprised sulphur, phosphorus, and carbon as its species – precisely the three actual substances of the table's class of acidifiable bases. And phlogiston itself was, of course, the phlogistic counterpart of two apparently new and particularly important substances in the table's class of the most simple substances, namely oxygène and calorique, the matter of heat.

In classes like these we thus encounter taxonomic units that were new and old at the same time. They were new, insofar as they presupposed the new antiphlogistic understanding of the substances concerned, and they were old in a classificatory respect, since they united exactly the same substances as their phlogistic counterpart. The awareness of this double-faced nature of certain classificatory features of the *Méthode*'s taxonomic table is essential for its historical assessment. Even the two webs of classes that form the backbone of the whole classificatory design comprise classes, and even pairs of classes, of such a double-faced nature.

³⁹ The classes of gases or compounds of calorique did not fit into this taxonomic scheme. Within this cluster of classes, there was no class whose composition could be regarded as analogous to that of any class of the two other clusters. Thus, the classes of gases had to be ordered into separate columns, namely columns II and IV.

⁴⁰ Elsewhere we have shown this in detail; see Klein and Lefèvre, *Materials in Eighteenth-Century Science*, part II.

⁴¹ See Klein and Lefèvre, *Materials in Eighteenth-Century Science*, chap. 9.

When we confront the table's taxonomic core structure with its phlogistic mirror image, the continuities and discontinuities between the Lavoisierian and the phlogistic chemical system become visible. For this purpose, let us juxtapose diagrams of both taxonomic structures (Figure 5). The comparison of the two diagrams shows almost at a glance how the Lavoisierian taxonomy relates to its phlogistic mirror image: a simple shift transforms the phlogistic mirror image into its antiphlogistic counterpart. One has only to exchange the places of the two pairs of analogous classes from column I to column III, and vice versa.

The theoretical change manifest in the two classificatory structures rendered in Figure 5 can be summarised as follows. Lavoisier's new chemical system entailed a radical new understanding of two pairs of analogous classes of substances, expressed by the symmetric exchange of their places within the classificatory web. Acids and metal calces lost their former status as (relatively) simple substances, and acidifiable bases and metals, which were formerly compounds, gained the status of (relatively) simple substances. This radical revision of fundamental chemical assumptions engendered by the new theory of combustion may deserve the designation "revolution." Against this view is the fact that this revision did not affect the principal classificatory structure in which inorganic chemical substances (simple substances and compounds) had been ordered since the beginning of the eighteenth century. This classificatory structure obviously had a more fundamental status in the early modern chemistry of these substances, than the fundamental assumptions revised by Lavoisier did. In other words, underlying both the phlogistic and the antiphlogistic chemical systems was a shared conceptual structure that remained untouched by this "revolution."

A document of transition

It has long been argued that the *Méthode* introduced a revolutionary rupture in the history of chemistry. To give just two examples:

There was a before and an after 1787. "La Méthode de nomenclature" introduced such a rupture in the history of chemistry that the natural language of the old chemists became a foreign language for us. All chemistry was profoundly modified.⁴²

...[C]hemistry provides one of the rare examples of the introduction of a new theory being accompanied by a general and widespread awareness of the sudden change in the theory and language of the science. Lavoisier's theory aroused a debate ...in which the traditional concept of chemical substances was questioned to its foundations.⁴³

⁴² "Il y eut avant et après 1787. La Méthode de nomenclature introduit une telle rupture dans l'histoire de la chimie, que la langue naturelle des anciens chimistes est devenue, pour nous, langue étrangère. Mais à travers ces changements d'habitude de langage, c'est toute la chimie qui a été profondément modifiée." Bensaude-Vincent, *A propos de 'Méthode'*, 1. By "rupture," rather than suggesting a sudden event, Bensaude-Vincent (well aware of the fact that the acceptance of the new nomenclature was a matter of a generation) wanted to highlight a radical break with the conceptual foundation of eighteenth-century chemistry.

⁴³ Beretta, *Enlightenment of Matter*, 246.

1. Anti-phlogistic

	I Simple substances	II	III I + Oxygen	IV	V III + I	VI
a						
b	<i>S/C/P-class</i>		<u>ACIDS</u>		Salts	
c	<i>Metals</i>		<u>METAL CALCES</u>			Alloy s
d	Earths					
e	Alkalis					

2. Phlogistic

	I Simple substances	II	III I + Phlogiston	IV	V I + I	VI
a						
b	<u>ACIDS</u>		<i>S/C/P-class</i>		Salts	
c	<u>METAL CALCES</u>		<i>Metals</i>			Alloy s
d	Earths					
e	Alkalis					

FIGURE 5 Shift of the pairs of analogous classes with linking function.

By contrast, what I have tried to uncover is exactly a shared conceptual foundation of all eighteenth-century chemistry, which was neither changed by Lavoisier nor by the authors of the *Méthode*. Ursula Klein has designated this conceptual foundation “the conceptual network of compound and affinity.” I argue that the authors of the

Méthode developed their chemical revisions and innovations exactly on this foundation – a foundation that can be regarded as eighteenth-century chemists' main contribution to modern chemistry, or, in other words, as the epitome of the transition from the period of alchemy to that of chemistry.

Notwithstanding its undeniable rank as a landmark in the history of chemistry, there are additional features of the *Méthode* that exhibit it as a document of an epoch of slow transition rather than a manifestation of a sudden revolutionary rupture. It goes without saying that the *Méthode*'s classification portrays the state of the art at a certain point in time, and that each change in this state must have repercussions. Its expiration date depended on the pace of developments in chemical investigations. Thus, some of the taxonomic distinctions and arrangements had to be revised within two or three years.⁴⁴

What is perhaps more important concerning the *Méthode*'s transitional character is the continuation of certain traditional assumptions other than taxonomic ones. One of these is the assumption of hypothetical components listed in column I, which have exactly the same hypothetical status as the former phlogiston: like phlogiston, they were defined as ordinary substances that could not yet be separated and isolated by existing chemical techniques. Besides the hypothetical simple substances already mentioned, viz. lumière, calorique, oxygène, and hydrogène, one finds twenty-three more such hypothetical substances in the first column for the simple substances.⁴⁵

Another feature shared with the chemical tradition is the *Méthode*'s designation of simple substances according to physical properties thought to be conveyed to their compounds. Thus, the name oxygène (derived from a classical Greek term for "sharp," "pointed," or "sour") highlights the assumption that the simple substance causes its compounds to be sour; or that azote (nitrogen, its name being derived from the negation of a classical Greek term for "living") causes its compounds to be suffocating. As observed above for phlogiston (its name was derived from the classical Greek term for "burnt"), such names attribute functions to substances that are reminiscent of similar functions of the Aristotelian elements and Paracelsian principles, and thus of the ontology connected with them.

Finally, the *Méthode*'s transitional character is manifest in a principal limitation that even threatened the new understanding of chemical substances with failure. The new, modern "conceptual system of compound and affinity" had been developed, as was shown above, by studying a special group of chemical substances

⁴⁴ In his *Traité* of 1789 Lavoisier proposed classificatory distinctions and distributions of chemical substances that amounted to a major revision of the *Méthode*: See Carleton E. Perrin, "Lavoisier's Table of the Elements: A Reappraisal," *Ambix* 20 (1973): 95–105; Robert Siegfried, "Lavoisier's Table of Simple Substances," *Ambix* 29 (1982): 29–48; Lissa Roberts, "Setting the Table"; and Klein and Lefèvre, *Materials in Eighteenth-Century Science*, 187.

⁴⁵ For the authors of the *Méthode*, acids were compounds composed of oxygen and a specific acidifiable base. Hence, there were just as many such bases as there were acids at the time – namely 26. However, the decomposition of acids and the separation of their acidifiable bases had been accomplished in only three cases – those of sulphur, charcoal, and phosphorus. This means that 23 of the 26 acidifiable bases were hypothetical substances.

that lent themselves to reversible decompositions und re-compositions. At the time of the *Méthode*'s publication it could not be readily applied to the bulk of substances chemists dealt with. As regards mixtures, this goes without saying, since the conceptual system is applicable to compounds only or to pure chemical substances (or to those we consider as such). But why could it not be applied to pure organic compounds as well? The reasons are material rather than conceptual. As a rule, the re-composition of organic compounds from their separated building blocks was beyond what was technically feasible at the time. Moreover, in the late eighteenth century, it was technically impossible to identify and collect all the organic components formed in the course of different chains of reaction. And this state of affairs did not change fundamentally – either by the emergence of electrochemistry around 1800, which provided new techniques for chemical analyses, or by refined methods and instruments of quantitative analyses. The dilemma is clear: without being applicable to organic compounds as well, the modern conceptual system of compound and affinity developed in the course of the eighteenth century could not become the conceptual foundation of modern chemistry.

In the second third of the nineteenth century, chemists like Jean-Baptiste Dumas and Justus Liebig succeeded in overcoming this stalemate. They found a new way of reconstructing organic chemical reactions that supplemented the laboratory method: the modelling of chemical reaction on paper by means of chemical formulas. As Ursula Klein has shown,⁴⁶ chemists began employing formulas not as a kind of shorthand for existing knowledge, but rather as “paper tools” that helped to create new knowledge.

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⁴⁶ Ursula Klein, *Experiments, Models, Paper Tools: Cultures of Organic Chemistry in the Nineteenth Century* (Stanford: Stanford University Press, 2003).