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7 The Power of Didactic Writings: French Chemistry Textbooks of the Nineteenth Century

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Textbooks have a bad reputation in science studies because they are considered the variety of scientific literature most remote from the creative source of knowledge. They are usually placed at the bottom of a long chain of writings stemming from laboratory notebooks, moving to oral presentations in larger and larger circles to journal articles, then to popular magazines, and finally to textbooks. If "the writing of textbooks is the last existential act in science," as John Brooke put it, it is clear that textbooks have nothing to tell us about the enthusiasm of creation, about the tangled labyrinth of the construction of scientific facts, or about the struggles with instruments and colleagues—all interesting facets of "science in action."[1] Historians of science consequently pay little attention to textbooks and use them only insofar as they provide a window onto "normal science."

Only a limited group of textbooks are mentioned by historians of science. In the case of chemistry, Lavoisier's *Elements of Chemistry* and Mendeleev's *Principles of Chemistry* are described as sources of knowledge. Lavoisier's decision to address beginners by proceeding from the simple to the complex and from the known to the unknown encouraged the foundation of a modern chemistry based on analysis. Mendeleev discovered the periodic law while he was striving to order the chapters of a general chemistry textbook intended for his students at St. Petersburg University.[2] These brilliant exceptions do not question the established general view of textbooks as repetitive, uninspired, and standardized expositions of pre-established knowledge.

In stark contrast with this long-standing tradition of despise for textbooks, Owen Hannaway argued in 1975 that the science of chemistry was shaped by textbooks.[3] The break between alchemy and chemistry was less a change of paradigm, such as the end of the belief in the possibility of transmutations or the rejection of alchemical and mystical symbolism, than a change in the exposition of chemistry. Chemistry became public knowledge as opposed to secrets transmitted from master to disciple. More specifically, chemistry became a teachable subject organized in a rational way. This was a real challenge because chemical knowledge mainly consisted in a tangled collection of recipes for preparing mixtures, and descriptions of their most striking properties or medical virtues. Hannaway located the didactic origins of chemistry as a science in Andreas Libavius's *Alchemia* (1597), although that book advocated a return to Aristotle. Starting with a set of definitions, Libavius attempted a classification of the recipes and processes in order to organize the chapters of his textbook. Thus chemistry gradually became a scientific discourse based on a set of general principles rather than a chaotic collection of empirical data. Hannaway did more than simply point out another famous textbook. He emphasized the heuristic power of didactic writing: as soon as a first classification was recognized it presented a new problem that others—readers and colleagues—would attempt to solve through new hypotheses and experiments. Libavius initiated a process of confrontation between organizing hypotheses and traditional empirical procedures. In thus revealing the creative power of writing a textbook, and the specificity of chemical knowledge, Hannaway acted as a pioneer. He opened up a Pandora's box of questions about the relations between didactic and scientific discourses. How could writing a textbook bring about scientific change? In which conditions could a textbook be creative? To what extent does the audience help shape the profile of a discipline? How did textbooks become established as a genre? How did they differ from other forms of chemical literature?[4]

This essay summarizes some results of our investigation of a corpus of about 500 textbooks published in France between 1789 and 1860. First we present the philosophical roots of the current image of textbook science in a brief preliminary section in order to contrast this image with the conclusions of our analysis of nineteenth-century textbooks. Then we describe the complex process of consolidation of French chemistry textbooks as a particular genre of scientific literature, paying attention to four actors: textbook writers, publishers, readers, and educational institutions. Finally, we discuss the issue of the creativity of textbooks through two typical subjects dealt with in nineteenth-century chemistry textbooks: classification and atomic theory.

Toward an Archeology of the Standard View

The distinction between creative science and expository science seems intuitive and quite natural nowadays, yet it is a rather recent view whose historical origin can be dated to the early nineteenth century. In France, it was clearly formulated by the founder of positivism, Auguste Comte. In the second lesson of his popular *Cours de philosophie positive*, Comte explicitly stated that the most advanced sciences could no longer be taught according to the chronological order of discovery. Teaching required a consistent and organic reconstruction of knowledge independent from the actual

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process of production of knowledge. Comte named it "the dogmatic order" by contrast to the "historical order" of exposition.[5] Although Comte stated that a science cannot be fully understood without its history, he considered the dogmatic order necessary for educative purposes. It is impossible, Comte argued, to raise an individual intellect, most often a mediocre one, to the level of knowledge acquired by many generations of geniuses. No individual, in a lifetime, can go through all the steps made by mankind. Hence the need for a shortcut—a logical reconstruction of the present state of knowledge. More than a simple gap, the dichotomy between the dogmatic and the historical orders required making a choice: either the historical presentation or the dogmatic presentation. Comte admitted that most textbooks were in fact a mixture of the two orders, but he insisted that such compromises were either inconsistent because the dogmatic order was incompatible with the historical exposition of science, or they relied upon biased accounts of the past.

Given this positivistic origin one might expect that anti-positivistic philosophers of science would question the dichotomy between the generation of knowledge and its didactic exposition. On the contrary, a century of textbook tradition seems to have reinforced it. Gaston Bachelard, for instance, insisted that the divorce was a characteristic feature of the scientific age, the unavoidable consequence of the break (the rupture) between the pre-scientific and the scientific spirits. While the former was unmethodical and wandering, the scientific way of thinking was "trained in official laboratories and codified in school textbooks." Bachelard emphasized that physics textbooks were repetitive and under a strict control. They supplied a "socialized and fixed science that could pass for natural only because of unchanging school syllabuses."[6] They were not descriptive but prescriptive, not really meant for transmitting science but rather commandments.

Thomas Kuhn added conservatism to the features of textbook science. Textbooks are meant for the perpetuation of the paradigm, for training students in solving the puzzles raised within the paradigm rather than inventing new problems.[7] Kuhn argued that they assume their conservative function through various ways. They present only established and incontrovertible knowledge, the stable results of past revolutions. They regularly occult revolutions either by eliminating history or by presenting the present state of knowledge as the end product of a linear accumulation of data. They consequently disguise the actual procedures both of discovery and justification. As training tools and rituals of introduction in a community, they are powerful precisely because they stabilize the discipline in denying scientific changes.

Despite doctrinal differences between them, Comte, Bachelard, and Kuhn agreed on various points. They assumed that the existence of textbook science (or of didactic exposition of science) is a necessity. They emphasized that textbooks did not mirror science in action.

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Textbooks, they all agreed, deliver a biased image of science, distorting the real nature of scientific activity for didactic purposes. Although Comte developed a gradualist, continuist view of scientific change while Kuhn and Bachelard advocated a discontinuist view with radical breaks and revolutions, they all agreed that textbooks belong to a regime of accumulation and reproduction of knowledge rather than to a regime of innovation and creation. While they characterized textbooks as mere transmission tools, none of them envisioned a possible impact of the audience on the contents of a discipline.

From this quick survey of the standard view of textbooks we derived a number of methodological decisions. First, we would not take for granted that the distinction between "textbook science" and "science in action" was necessary or natural. Rather we wanted to examine in which contexts the dichotomy between the creation and transmission of science was generated. We consequently focused on the circumstances and constraints in which textbooks emerged as a genre of scientific publication. The middle of the nineteenth century appeared as a turning point, at least in France. Second, we would not discuss textbook science from the unique standpoint of science studies. As tools intended for the transmission of a set of knowledge, textbooks are written and manufactured for the specific audiences created by educational measures and reforms. We had to identify the heterogeneous agents that interact in the production of textbooks: the contents of chemistry, the students attending courses in various educational situations, and the authors with their backgrounds and professional activities, which shaped their personal views on chemistry and teaching. Insofar as chemistry textbooks are located at the intersection between the advancement of science and pedagogical views, they are under strong social, economic, and political pressures. In teaching spaces, as Kathryn Olesko emphasized, economic, social, and political forces rush into the structure and function of scientific knowledge.[8] This means that we had to revise the present image of scientific teaching as a second-rate scientific activity. Moreover, textbooks are material and commercial products subjected to the technical, financial, and political constraints of the publishing market. As such they belong to the history of books and reading. Therefore a historical study of science textbooks should intertwine the history of scientific disciplines with the history of science education as well as the history of books and publishing.

The Consolidation of an Editorial Genre

How did textbooks turn into an independent and characteristic genre of scientific publication? The answer to this question raises a methodological difficulty: how to define the object under study. In the first half of the nineteenth century, various types of scientific literature acquired identities of their own as editorial products and as instru-

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ments of scientific communication. Science journalism, popular books, technical handbooks, encyclopedias, dictionaries, and various other types of publications settled in the publishing market while scientific communication was expanding.[9] These scientific genres involved sets of conventions which were shared by authors, publishers, and readers. As T. H. Broman remarked, "any writer who sets out to write a textbook, or a dissertation or scientific research article for that matter, must take into account those conventions and practices that permit a writing to be recognized and accepted by readers as an exemplar of a particular genre."[10] However, scientific genres were never stable realms with sharp and airtight boundaries. On the contrary, they were continuously negotiated and transgressed by readers, authors, and publishers, who might produce literary experiments in order to broaden their audiences.[11] Textbooks interacted and sometimes overlapped with other scientific publications because they shared publics, uses, and objectives. How to distinguish a textbook for primary education from a popular text, a general course of chemistry from a treatise, or even a handbook of experimental chemistry from a catalogue of instruments?

Two possible definitions are available. Either textbooks are defined by their uses—a textbook is every text practically used as a didactic tool in teaching institutions—or by their purposes—a textbook is every text especially and explicitly designed to be used as a didactic instrument in teaching institutions. Each definition suggests different sources and questions.[12] The former would lead us to focus on teaching practices and on the various uses of the text as a didactic tool. The latter, on the contrary, takes us to a history of the concept of textbook as it was designed and materialized by the various actors converging on the production of this type of text. The latter definition will be adopted in this essay. This means that our main subject is a group of books that, according to the indications that authors and editors included in the titles, covers, or forewords, were expressly written to be used in chemistry teaching in specified institutions. The election of a definition based on purposes and not on uses is determined by the sort of questions that lead our analysis. We aim to determine when chemistry texts conceived for teaching purposes started to have characteristics of their own, and we attempt to clarify a periodization of the emergence of chemistry textbooks as an autonomous editorial genre. First we try to assess the impact of the changing audiences for chemistry. Then we discuss the shifting biographical profiles of textbook authors and publishers as well as the main features of the French nineteenth-century textbook market. Whereas historians are usually more concerned with the description of the social aspects of this process of institutionalization, we will emphasize the consequences of institutional changes and consider how the contents and practices of a scientific discipline were adapted to new audiences, changing spaces, and teaching practices. As traces

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of teaching practices, textbooks are a privileged source. In less than six decades they were transformed into didactic tools with distinctive features.

The educational reforms introduced during the French Revolution transformed science teaching. In the eighteenth century chemistry had been taught in public courses with no regulations. Chemistry lectures were attended by medical and pharmacy students, artisans and craftsmen interested in practical applications, as well as by the gens du monde attracted by the spectacle of experimental demonstrations. After the French Revolution, by contrast, chemistry became an integral part of the official syllabus in a number of teaching institutions. It was taught at the secondary level in the écoles centrales and lycées, as well as in the institutions of higher education—écoles normales supérieures and facultés des sciences—dedicated to the training of teachers.[13] It was also an integral part of medical and pharmaceutical studies, which reinforced its importance in secondary teaching.[14] Simultaneously, chemistry was fully integrated in engineering schools, from the Ecole polytechnique and its écoles d'application to the military academies.[15]

The institutionalization of chemistry teaching had a tremendous impact. First, it increased the number of chemistry students and teachers.[16] However, the most important changes were less quantitative than qualitative. The heterogeneous audiences of public courses became a captive public, with specific capacities and training necessities that varied according to the different levels and institutions in which chemistry had been integrated. Classrooms reserved for regular students replaced the auditoriums and private laboratories open to everyone interested in acquiring chemical knowledge. School schedules, syllabi, and procedures of control limited the freedom of the teacher.

A Captive Public

Textbooks, as objects tailored for specific targets, are defined by their publics. Their contents, format and size, typographic and iconographic features, and even the author's and editor's experiences were meant to supply the demands of a targeted reader according to his or her previous knowledge, age, and cognitive capacities, as well as to the didactic requirements, methods, and practices of an institution. In stark contrast with the standard references to heterogeneous publics found in most eighteenth-century chemistry texts, the didactic books published during the first decades of the nineteenth century contained more and more precise indications about the reader they targeted. The covers and forewords were the usual places to define the ideal public that editors and authors had in mind when writing, manufacturing, and selling a textbook. They offer clues about the horizon of expectations of the intended readers, their background, institutional context, and professional perspectives.

Chemistry textbooks in early-nineteenth-century France were meant for two types of students: medical and pharmaceutical students, and the pupils of the secondary education schools. The latter group disappeared under the Restoration when chemistry was banished from secondary teaching; hence there was a sudden drop in textbook production (followed by a second boom of production in the middle of the century, when chemistry was reintroduced at the secondary level). In fact, the two groups overlapped, since most of the pupils who attended the chemistry courses in the lycées were future students of medicine. After the reorganization of medical and pharmaceutical studies in 1803, chemistry became a propaedeutic subject for both curricula. An examination in chemistry was one of the six compulsory exams that every candidate for the doctoral degree in medicine had to pass. The French Revolution opened two possible ways to become "maître en pharmacie": either the traditional eight years of practical training at the apothecary office, or three years of practice followed by three years of study in one of the pharmacy schools in which chemistry played a major role in the curriculum.[17]

In addition to the students of the medical faculties or the pharmacy schools, students who attended the innumerable private preparatory courses were a favorite target for textbooks. These courses, already established in the eighteenth century, proliferated during the first half of the nineteenth century, especially when the grade of baccalauréat ès sciences became compulsory to enter the Faculty of Medicine. In Paris, the Faculty of Medicine hosted and supported these private courses. The director, J. Tyrat, delivered his course in daily lectures of four hours over a period of two months. Students who attended the private lessons could use the physics cabinet and the chemistry laboratory available on the site. The contents of the courses were strictly adjusted to the exam. Teachers were supposed to define their questions in the same terms as "MM. les examinateurs" did, and to encourage their pupils to answer them in the manner required for the exam.[18]

Thus future medicine and pharmacy students became the main target of the chemistry textbooks published during the first decades of the nineteenth century. During the second third of the century, however, the readership diversified. As chemistry was reintegrated in secondary education as a compulsory subject, there was a dramatic increase in textbook production. From 1830 on, dozens and dozens of texts for the students of the collèges royaux (as secondary institutions formerly named écoles centrales and then lycées were rechristened under the Restoration) were published, and in the late 1840s the first best-sellers were reprinted. Simultaneously a large variety of "manuels" and "aide-mémoire" specifically intended for the preparation of the baccalauréat flooded the market.[19] In 1833, Guizot's law, reorganizing primary education, created an intermediate cycle intended to cover the gap between primary and secondary studies.

Among other subjects, the official syllabus included "notions of physical and natural sciences applicable to daily uses." Consequently, chemistry became part of the teaching in the écoles normales primaires, where future teachers were trained.

In addition to educational policies and official syllabi, local technological institutes interested in the applications of chemistry to arts and industry also contributed to enlarge the public audience for chemistry. Starting in the 1830s, they organized evening lectures and Sunday courses for training specialized workers.[20] Simultaneously, private initiatives led to the creation of teaching centers such as the Conservatoire national des arts et métiers and the Ecole centrale des arts et manufactures of Paris. These specific audiences of workers and manufacturers prompted very successful textbooks such as the *Leçons de chimie élémentaire faites le dimanche, à l'Ecole municipale de Rouen* by Jean Pierre Louis Girardin, reissued eight times between 1835 and 1889, or the eight-volume *Traité de chimie, appliquée aux arts* by Jean Baptiste Dumas, based on the courses delivered initially at the Athénée of Paris and later at the Ecole centrale des arts et manufactures.[21] Chemistry textbooks for technological education formed a heterogeneous group that reflected the diversity of publics interested in the applications of chemistry. For instance, Anselme Payen (1795–1871), a chemistry professor at the Conservatoire national des arts et métiers, published different versions of his course on industrial chemistry in order to reach a variety of audiences. After the first version intended for the gens du monde, he targeted the students of the écoles préparatoires aux professions industrielles and those of the écoles d'art et manufactures, ending up with a volume for "manufacturers and farmers."[22] In contrast to Payen's pragmatic vision of the capacities and interests of his potential readers, Dumas adopted a more idealistic view in the preface to his treatise. He assumed that it would be accessible to a new generation of readers trained in the secondary collèges royaux, and able to apply the theoretical knowledge of chemistry to arts and industry.[23]

As a result of this strategy of diversification, the audience of chemistry textbooks was enlarged. However, as already mentioned, the most striking changes were less quantitative than qualitative. First, the public was captive and subject to teaching and reading practices determined by the spaces and the didactic methods of the time. Second, it was segmented into various layers according to the levels and types of teaching. For each category of book, authors and editors forged a demand, a curiosity, or an urgent and imperious necessity for filling lacunae. Every textbook appeared as supplying a market demand. In 1828, A. Manavit, a professor at the Collège royal in Toulouse, who published one of the first manuals for this kind of institution, presented his text as "an intermediate genre between big treatises and abrégés whose value hardly exceeds that of a table of contents." His textbook was specifically conceived to "help the pupils attending the elementary course of physics and chemistry which the author of this précis is in charge of at the Collège royal of Toulouse, in order to smooth a number of difficulties in their baccalauréat examination, and to allow them to fruitfully attend further courses at the universities."[24] Audiences, we claimed at the beginning of this section, defined textbooks; but it is also true that textbooks helped create and stabilize a diversity of audiences.

Heroic Authors vs. Obscure Writers of Best-Sellers

Who wrote chemistry textbooks, and why? It is easy to answer the question for the late eighteenth century and the early nineteenth century. The biographies of Lavoisier, Chaptal, and Fourcroy are well known, and their motivations to write textbooks are easy to understand in view of the scientific changes prompted by the chemical revolution and the institutional changes caused by the French Revolution. It is somewhat more difficult to understand the motivations of Louis Jacques Thenard, Mateu Orfila, or Jean Baptiste Dumas, whose books were reissued periodically and used as references for the teaching of chemistry during the first half of the nineteenth century. The task, however, becomes considerably more difficult when we turn to authors such as Mathurin Jacques Brisson, Pierre Jacotot, Jean Baptiste Jumelin, Roch Théogène Guérin, Edmond Jean Joseph Langlebert, Jean Louis Lassaigne, Henry Debray, Eugène Desmarest, Pierre Paul Deherain, and Nicolas Deguin. Some of them authored successful textbooks used by several generations of students. Their names were certainly familiar to nineteenth-century French people, even if they have not been passed down to posterity. They skipped out of history despite the various traces of their publications in French libraries. Biographical sources to study this community of obscure chemistry writers are available, but their activity has been disregarded by historians of science.

The image of textbooks as mere instruments of transmission of knowledge reduces the role of their authors to an exercise in transcribing, summarizing, or adapting knowledge that was already organized. As we will argue below, writing a textbook was much more than passively transmitting pre-established knowledge. Instead, textbook authors acted as mediators among the actors that converged in the production of textbooks. As authors they engaged in the creation of didactic tools adapted to certain categories of readers and to the material conditions and requirements of teaching institutions. Not only did they have to be in agreement with the official norms and regulations that ruled the public educational system; since books are material objects, they also had to adjust to printing technologies and to publishers' editorial policies. From this angle, the profiles of those obscure people who devoted part of their time to textbook writing looks more interesting. Were they motivated by scientific views or by career, financial, political, or ideological interests? What were their backgrounds, their institutional positions, and their professional activities in research and teaching?

Prosopographic study suggests three periods in the evolution of the biographical profile of textbooks writers. In the first period (1789–1808), the authors aimed their books at the new teaching institutions created during the Revolution. The writers in this first generation were the most heterogeneous. Their contrasting backgrounds, professional activities, and involvements in academic research reflects the diversity of situations in which chemistry was cultivated during the second half of the eighteenth century. However, they shared a common feature: almost all of them had been recruited as teachers for the new educational institutions of the République. They had been trained during the Ancien Régime. Their backgrounds ranged from theology in the case of Pierre Jacotot (1755–1821), to military training in the case of Pierre Auguste Adet (1763–1834), to medicine or pharmacy in the cases of Edmé Jean Baptiste Bouillon-Lagrange (1764–1844) and Jean Baptiste Jumelin (1745–1807). Their textbooks were published late in their careers and lives. Some of them, such as Mathurin Jacques Brisson (1723–1806) and Jacotot, had many years of teaching experience in the Ancien Régime institutions. Others, such as Adet and Bouillon-Lagrange, were recruited because of their political engagement or their research achievements.

During the first two decades of the nineteenth century a radical change took place in the biographical profile of chemistry textbook authors. Authors were mainly young medical doctors (and sometimes pharmacists) who published in an earlier stage of their professional careers. Most of them taught students of the private preparatory courses for the entrance exam in medical faculties or medical students preparing chemistry exams at the Faculty of Medicine, or candidates for the degree of maître en pharmacie. For more than twenty years these students learned the foundations and the applications of chemistry through the texts written by authors such as Mateu Orfila, Jean Louis Lassaigne, and Julia de Fontenelle, members of the Société de Chimie Médicale, editors or active collaborators of the *Journal de Chimie Médicale*. They published their works in the publishing house of Nicolas Crochard, associated with the Paris Medical Faculty. In contrast with the heterogeneous group of the previous generation, authors and publishers of this period belonged to the medical milieu and shared common backgrounds, professional interests, and institutional contexts.

During the third period, the 1830s and the 1840s, the influence of the medical milieu was diluted with the revival of chemistry in French secondary education. A community of authors emerged with a new standard biographical profile. They had been educated in the same institutions in which they became teachers. Most often they published their textbooks early in their careers. Textbooks were neither mature works nor the culmination of scientific or teaching activities.[25] The uniform biographical profile of authors of secondary-school textbooks contrasts with the variety of positions that we find among authors of textbooks for primary and technical education. They ranged from secondary teachers to engineers formed at the Ecole polytechnique who wrote small elementary and practical manuals at the end of their careers, including doctors such as Adolphe Dupasquier (1793–1848) and industrialists without university degrees such as Anselme Payen (1795–1871).

Publishers: Between the Government and the Market

In nineteenth-century France, education gradually became a state monopoly. The various governments attempted to control the contents of science teaching through various systems.[26] During the Revolution and the Empire, textbooks were the main instrument of control.[27] A committee of experts appointed by the government selected the "official manuals," preferably a single one that would guarantee uniform contents in all public and private institutions. The attempts to impose a unique text were especially strict and persistent for secondary education, which was a major concern for all governments. A commission formed by Laplace, Monge, and Lacroix was in charge of designing the syllabus for secondary school and choosing the official textbooks in 1802. Finding no adequate book on the market, they decided to commission a chemistry textbook from the "citizen Adet."[28]

As several attempts to impose an "official manual" failed, a new system was adopted consisting of the publication of a list of authorized textbooks that teachers must use. This system began in 1809 when secondary education was integrated into the Université impériale, prescribing that "all kinds of lectures will be shaped after the classic or elementary printed books, according to the statement attached to the present regulations." Moreover, the "grand-maître" had the right to commission new books when the texts available were judged inadequate. Teachers were free to select the book of their choice from the list, and their decision had to be publicized at the beginning of the course. The list of recommended chemistry texts included Lavoisier's *Elements of Chemistry*, Fourcroy's *Chemical Philosophy*, and Berthollet's *Statique chimique*, and extracts of them could be read in the class by the teacher.[29] Similar lists were published in the following years, and some of them were extremely restrictive. In 1814 the only recommended text was "la chimie de Thenard," which was assumed to be the only one able to relate the most advanced state of chemistry.[30] The reform of 1821 was a turning point in the control of secondary education.[31] Textbooks had to adapt their contents to the official syllabus, but teachers retained the freedom to chose their textbooks. It became the publishers' responsibility to ensure that the textbooks' contents were properly adapted to the mandated syllabus. With this reform, publishers acted as a controller or censor in the name of the government.

As publishers played the crucial role in the process of textbook production, the number of textbooks published increased. More generally, chemistry textbooks followed the general trends of the book market. First, as textbooks in general became one of the main pillars of the book market during the second third of the nineteenth century, they were clearly recognized as an independent editorial genre. Second, our study shows a remarkable process of specialization.[32] In the catalogues of printers and booksellers of the early decades of the nineteenth century, chemistry textbooks were close neighbors of big treatises, specialized monographs, dictionaries, and scientific journals. For instance, Berard and Klosterman, booksellers of the Ecole polytechnique, published the five editions of the *Manuel de chimie* by Bouillon-Lagrange, an important textbook initially written for the students of the Ecole polytechnique and then slightly modified to be used at the Ecole de pharmacie. In addition to a long list of books intended for engineering schools, Berard and Klosterman's catalogue also included prestigious scientific journals such as the *Annales de chimie* and the *Bulletin scientifique* of the Société Philomatique, along with a translation of Thomson's *System of Chemistry*.[33] Nicholas Crochard, another publisher who specialized in medicine and who printed the *Annales de chimie* in 1814, had in his catalogue the two most important chemistry textbooks—Thenard's *Traité de chimie élémentaire* and Orfila's *Eléments de chimie appliquée à la médecine et aux arts*—as well as several manuals intended to aid students in preparing for the Baccalauréat.

Specialization occurred in the 1830s when publishing houses such as Victor Masson gave priority to textbooks in their catalogues. Between 1840 and 1845, Fortin-Masson et Cie published numerous chemistry textbooks such as the *Leçons de statique chimique des êtres organisés* by Dumas and Boussingault, Fresenius's and Gerhardt's treatises of chemical analysis, and several translations of Liebig's textbooks. When Victor Masson took over, textbooks for secondary education prevailed so much that Masson reissued most of the textbooks in the middle of the century, such as Regnault's *Cours élémentaire de chimie* and the various versions of Fremy's and Pelouze's chemistry courses. Louis Hachette, founded in 1826, published the first chemistry textbook for secondary education in 1828 and quickly gathered most of the textbooks for primary and secondary education. Thus, in a few decades the production of textbooks became the monopoly of a few publishing companies. At the same time there was a centralization of most publications in the capital, which prompted the decline of publishing houses in the provinces.

Publishing contracts are privileged sources with which to learn about the negotiation between authors and publishers and better understand the role played by the former.

Unfortunately these scarce and dispersed sources are difficult to find.[34] From a contract signed in 1825 by Béchet jeune and Labé, publishers and booksellers of the Paris Medical Faculty, with Jean Baptiste Dumas for the publication of his future treatise of chemistry, we may infer that publishers introduced in the contract several clauses concerning the structure of the text, its distribution in different volumes, formats and sizes, and so on. In this case, the text had to be "divided into two distinct treatises, one of general chemistry, the other of chemistry purely applied to arts and agriculture, each one comprising four 700 to 800 page volumes in 8 [octavo]; in case this division occurred, each edition of both treatises would be issued in 4,000 copies and [the author] would be paid 7,500 francs for each volume."[35]

This was not a negligible income for the young Dumas, who in a letter to Liebig angrily complained about his "difficult existence" in Paris with an annual salary of just 2,000 francs from his post as "répétiteur at the Ecole Polytechnique."[36] Nor was the economic profit of textbook writing irrelevant for the young Orfila. At a time when his economic resources were limited to his private lectures, he received 5,000 francs from Nicolas Crochard for the first edition of the *Toxicologie générale* in 1813.[37] Similar profits were also relevant for many other authors, such as Nicolas Deguin, who was a secondary-school teacher (with an annual salary of 2,000 francs) and later a professor at a provincial Faculty of Science (between 4,000 and 5,000 francs) during the 1840s. By the middle of the nineteenth century, more than 30,000 copies of Deguin's book on physics had been sold. Deguin also published several editions of his textbook on elemental chemistry.[38] Even for the Parisian mandarins, whose practice of "cumul" gave them larger incomes, the significant money that could be made by writing textbooks was probably an important inducement.[39]

Publishers not only encouraged authors to write textbooks by offering a substantial economic income; they also shaped the material characteristics of chemistry textbooks. In the hands of a few Parisian publishing companies, endowed with power by the official system of control, the material aspects of textbooks quickly differentiated them from other kinds of publications. Publishers highlighted their favorite authors and designers while making all efforts to reduce the costs. As a result of this commercial strategy, small formats with a limited number of pages became the standard during the first half of the nineteenth century, with a specific size for each teaching level. Secondary education textbooks turned into single volumes in octavo format with no more than 500 pages. Only textbooks for technical and superior education continued to be published in two or more volumes. The smaller formats in duodecimo and sextodecimo format, with no more than 200 pages, were reserved for the small hands of primary-school children.

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By the mid 1830s, new printing techniques adopted by the big publishing houses changed the material presentation of textbooks and transformed them into a clearly distinguishable type of publication. Such formal changes also had important consequences for textbooks' content. Typographic innovations allowed a hierarchy of information printed on a page, with small characters for technical descriptions or experimental procedures alternating with bigger and bold ones for titles and main ideas. Another result of new engraving techniques was that pictures formerly gathered at the end of the volumes were integrated within the body of the text, and their quality improved. With more detailed though cheaper engravings, textbooks incorporated an increasing amount of visual material, including more realistic representations of instruments, chemical reactions, physical phenomena, industrial processes, and natural landscapes. New images changed not only the way in which experiments, instruments, and phenomena were represented but also the way they were described and explained. In the beginning of the nineteenth century, textbooks had routinely featured long and detailed descriptions of experiments intended to "mettre les élèves dans le cas de les répéter toutes," as Thenard put it.[40] Over time these gave way to short texts giving a few technical details of a chemical reaction expressed analytically by an equation, and including pictures of experimental devices in realistic engravings.[41]

Textbook Creativity

The common view of textbooks as uncreative and passive vehicles of knowledge conveys not only a particular image of the divorce between research and teaching activities in science but also a static picture of scientific literature. Many eighteenth-century chemists included original research in their textbooks and claimed that they had to perform additional experiments in order to write them.[42] In the nineteenth century, textbooks rarely reported original or new substantial experiments. Yet even in this later period, writing a textbook implied making decisions about structure and contents. This was rarely a personal decision of writers. Rather it was the result of negotiations among a group of actors, including the targeted audiences, publishers, and printers. To discuss the issue of creativity in textbooks, we therefore must abandon the clichés about scientific discoveries as "eureka moments"; it will do us little good to fall back on heroic narratives such as those constructed by nineteenth-century chemist-historians and their followers. By "creativity" we do not even necessarily mean discoveries or scientific innovations. Rather we have in mind any original interpretation of scientific phenomena expressed through writing and teaching, whether or not this original view was accepted and became part of "normal science." We explore the features of textbook

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creativity through a closer examination of two important issues debated in nineteenth-century chemistry: chemical classifications and atomic theory.

Looking for an Order of Things

Concerning classifications, historians of chemistry implicitly assume that modern classifications emerged through two founding events: Lavoisier's *Elements of Chemistry* and Mendeleev's periodic system.[43] Both episodes have a common feature: they are among the rare cases in traditional historical narratives in which a creative moment is clearly associated with a pedagogical practice, that is, the act of writing a textbook. Yet *all* textbook authors—not only Lavoisier and Mendeleev—had to deal with classifications of chemical substances in order to organize the chapters of their books. It is therefore legitimate to discuss the creative power of textbooks over a broader sample of textbooks than the two illustrious cases. We shall focus on French textbooks published between these two alleged "founding events."

Lavoisier's *Traité* was not the first textbook to include a plea for the "simple-to-complex" order and the "known-to-unknown" didactic structure. A number of eighteenth-century textbook writers, such as Antoine Baumé, claimed that they moved "from the simple to the compound and from the compound to the more compound."[44] This order, whether called analytic or synthetic, had prevailed in the exposition of chemistry for a few decades before Lavoisier resumed it along with the redefinition of the notion of element as a simple substance. Moreover, Lavoisier's assumption of an identity between the two principles—from simple to complex and from known to unknown—is also found in mid-eighteenth-century textbooks.[45] In following an old textbook tradition, Lavoisier nevertheless increased the importance of chemical analysis in nomenclature and classification. Substances formerly classified as compound, such as metals, turned out to be elementary substances (and vice versa), while an increasing bulk of data concerning elementary analysis became available at the end of the eighteenth century.

In 1800, Antoine de Fourcroy claimed that chemistry would soon be emancipated from natural history thanks to a chemical classification based on the nature and proportion of the constituent principles.[46] According to Fourcroy, the autonomy of chemistry involved the passage from external, visual, physical features to internal, compositional organizing principles, or, as Gaston Bachelard later commented, the replacement of "immediate physical analogies" by "rectified chemical ones."[47] In fact, the change was gradual as the analytical order did not subvert more traditional arrangements. Moreover, the simple-to-complex compositional principle did not solve all the problems related to chemical classifications. For instance, three authors who claimed to follow this principle (Chaptal, Lavoisier, and Fourcroy) wrote very different textbooks indeed during the late eighteenth century.[48] Several choices were available to writers. Many chemical substances were "equally" elementary (or compound). The classification of chemical elements, whose number dramatically increased during the first half of the nineteenth century, required additional criteria. And so did the sequence of the much more numerous chemical compounds, which largely depended on the arrangement of elements.

More criteria meant more problems of congruency. Jacques Thenard—the most influential chemistry textbook author during the first third of the nineteenth century—explicitly employed three organizing criteria: from simple to complex, from known to unknown, and chemical analogies.[49] Although generally accepted by chemists as almost identical, the simple-to-complex order and the known-to-unknown principle raised dilemmas. Admittedly, simple substances should be taught first, although they were largely unknown to beginners. Water, air, and other compound bodies had to be introduced much later.[50]

Compatibility between chemical properties and chemical composition raised more vexing problems. Early-nineteenth-century authors implicitly assumed the existence of a straightforward relationship between elemental composition and chemical properties. In this case, groups based on chemical composition would be congruent with the groups of chemical analogues. But unforeseen divergences occasionally emerged. For instance, Thenard adopted the affinity for oxygen as the leading organizing principle. He applied it not only to simple bodies—non-metals and metals—but to plant and animal principles as well. Relying on Lavoisier's theory of acidity, he regarded acid substances as binary compounds of oxygen and another non-metallic element. Alkaline substances were considered to be binary metallic oxides. Since Thenard's treatise was officially a model for all French textbooks during the first third of the nineteenth century, his classifications were largely adopted, and his classification of metals into six groups survived until the end of the nineteenth century.[51]

In the early nineteenth century, most of the known substances fit Thenard's general schema. However, the discovery of new elements and the "exaggeration of the role of oxygen"—as Ferdinand Hoefer described Thenard's classifications—raised more and more inconsistencies during the 1820s and the 1830s.[52] Ammonia, hydracids, new metals, alkaloids and other newly discovered compounds hardly fit in the scheme.[53] In the sixth and last edition of his textbook, published in 1835–36, Thenard attempted to introduce major changes in his classification in order to face these problems. The institutional context encouraged such changes since a new generation of textbooks was under way for the reintroduction of chemistry in secondary schools.

The younger generation of teacher-authors returned to an older debate between natural scientists: artificial versus natural classifications of chemical elements. In artificial classifications, instantiated by Thenard's choice of the affinities for oxygen or Berzelius's choice of electrical charge, elements were arranged according to one single property, one single character; in the latter, exemplified by Louis-André Marie Ampère's essay published as early as 1816, all of the elements' properties and characteristics had to be taken into account.[54] Ampère criticized the overestimation of oxygen in chemical classifications and suggested a natural classification based on "all the characters of the bodies," so that groups of substances with "the most numerous and essential analogies" might be created.[55] Ampère thought that the "natural order" could be unveiled by the "natural method." Ampère offered a circular arrangement of chemical elements in which properties changed gradually from one group to another, and he emphasized the similarities between bodies placed at the edge of the chain.[56] Ampère distinguished three major families ("gazolytes," "leucolytes," and "chroïcolytes"), which were further subdivided into 15 genres.[57] Ampère's essay raised no enthusiasm among the French chemical community in 1816. It was "rediscovered" in the 1830s and the 1840s when the new generation of textbook writers became more and more concerned about classifications. The debate reached a climax in 1845 when Ferdinand Hoefer (1811–1878), a chemist and historian of chemistry, published a small book about this issue, in which no fewer than eight different chemical classifications were presented.[58]

Although Ampère's essay became the standard reference for the advocates of natural classifications, it was never a model. A first important attempt to introduce natural classifications in secondary-school chemistry textbooks was made by Gay-Lussac's répétiteur at the Ecole polytechnique, César Mathurin Despretz (1791–1863).[59] Despretz was also a teacher of physics in the prestigious Collège Henri IV. In 1828–29 he authored a *Traité de chimie* in which he claimed to adopt a "completely new" order in chemistry while following "what had been done in botanic and natural history." Instead of "arranging the bodies by their affinity for oxygen, hydrogen or other bodies," he made families by "placing together those that had most resemblances."[60] Yet Despretz disagreed with Ampère about the choice of classificatory criteria and chose "more chemical criteria, so to speak."[61] In fact, Despretz's arrangement of metals was more similar to Thenard's artificial classification than to Ampère's natural one.[62] Relying on his eight years of teaching experience, Despretz bragged about the didactic advantages of his natural classification, which conveyed "general ideas" and "relationships that were not shown by artificial classifications."[63]

Despretz was no exception in the 1830s and the 1840s. Most textbook authors did not copy or passively adopt a classification. Rather they discussed the issue, compared

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various systems, and tried to create their own natural classification. As a result, a variety of systems were found in French chemistry textbooks during the 1830s and the 1840s, coinciding with the diversification of audiences and the emergence of new authors and publishers. Textbook authors were free to decide on the arrangement and contents of their textbooks, since the regularly published official syllabus only defined guidelines for lectures. The 1828 syllabus for the collèges royaux, partly written by Thenard, did not give any indication about the order of exposition.[64] The 1837 syllabus for the baccalauréat-ès-sciences physiques included an arrangement of non-metals along Thenard's artificial classification but no recommendation for the classification of metals.[65] The syllabus for the baccalauréat-ès-lettres (1840) and the classe de philosophie (1843) was even more elusive.[66] Only with the 1852 deep reform of secondary schools did the official syllabus prescribe a definite classification.[67]

The 1852 reform was mainly influenced by Jean Baptiste Dumas, who had developed a concern for classification. Dumas first attempted a natural classification in his 1826 work on chemical atomism. By using "atomic volume," heat capacity, and "modes of combination," Dumas aimed to create a natural classification in which substances whose "molecules had similar properties" were grouped together. This kind of classification, he claimed, would make the study of chemistry easier and, at the same time, would lead to "the discovery of new compounds" by displaying "fair analogies."[68] In 1828, when he wrote the first volume of this textbook, Dumas again praised natural classifications. He arranged non-metals according to the number of atoms of these elements that combined with hydrogen.[69] In subsequent years, other chemist-authors followed Dumas's attempts to create natural classifications by using chemical atomism. Alexandre Baudrimont (1806–1880), a disciple of Ampère and a staunch advocate of atomism, ventured a natural classification in his *Traité de chimie*.[70] Baudrimont's natural classification was founded on his concept of "isodynamic bodies" ("corps isodynamiques"), defined as substances which might replace each other in chemical compounds.[71] The result was a complex system in which an element could be included in two or more of fourteen series.[72] The future of chemistry, however, seemed to lie in natural classifications based on atomic properties. Even the leader of artificial classifications, Jacques Thenard, wrote in his *Philosophie chimique* (1836) that "if ever chemistry possesses a natural classification, it will be grounded on isomorphism."[73] Thenard praised Dumas's classification of non-metals according to "nature, proportions and mode of condensation of their combinations with hydrogen" as "generic characters," and he mentioned other characters, such as electrical or heat conductivity and atomic weight, which were also employed as "specific properties."[74] Taking into account "isomorphism" and "chemical properties of bodies," Hoefer proposed a classification with eleven natural families of elements. In 1841, Hoefer claimed that the time for artificial classification was over and that even the old dichotomy between metals and non-metals should be rejected because it was not "rigorously scientific."[75] He even pretended that Thenard's artificial classification was "generally rejected."[76]

Despite Hoefer's optimistic remarks, natural classifications did not win the battle. While Dumas's natural classification of non-metallic elements was adopted by a majority of textbook writers, Thenard's artificial classification of metals, amended by Henri Victor Regnault (1810–1878) in 1836, was still largely used.[77] Dumas himself, who offered some hints about a natural classification of metals in the second volume of his textbook,[78] finally retreated and adopted an artificial classification slightly different from Thenard's in the third volume dealing with metals.[79] According to Favrot, a private chemistry teacher and a "préparateur" at the School of Mines, Thenard's artificial classification of metals should be employed in textbooks because it was based on "easy-to-learn characters." Ampère's classification, on the contrary, did not have any "salient character" that could be employed to distinguish one group from another.[80]

The same concern was shared by the author of one of the last French attempts at natural classification. Adolphe Dupasquier (1793–1848), a teacher of chemistry at the Ecole de la Martinière in Lyons who published the first volume of a *Traité élémentaire de chimie industrielle* in 1844, regarded natural classification as the most logical one ("la plus logique").[81] Yet he also emphasized its difficulties. On the one hand, several substances were still not known well enough to establish their chemical analogies. On the other hand, Dupasquier thought that it was "an almost insensible passage from the properties of one body to another." All bodies were related by "a general link" ("une liaison générale"), which made a perfect grouping impossible; none could satisfy all points of view.[82] All attempts at natural classification having failed, Dupasquier claimed that time had come for a compromise combining natural and artificial classifications.[83]

A hybrid natural-artificial classification was institutionalized by the 1852 official syllabus decreed by Minister Fortoul after the bifurcation of the two sections "sciences et lettres" in secondary education. The new syllabus, written by Dumas and other scientists, recommended "the classification of non-metallic bodies in four natural families" while metals were arranged according to Thenard's artificial classification.[84] Although this hybrid system was presented as an imperfect and temporary solution, it prevailed until the end of the nineteenth century, as the most successful textbooks published in the 1850s went through more than twenty editions.[85] Thus the impetus that had fostered the search for chemical classifications in French textbooks for two decades was stunted in the middle of the nineteenth century. This stagnation resulted mainly from the imposition of the official syllabus, which froze a temporary system and drastically reduced teachers' and authors' margin of freedom. Yet this does not mean that the creativity of textbooks had been exhausted. Rather, authors displaced their interest to other issues, over which they exercised their power of decision.

Atoms and Molecules in Textbooks

Did the contemporary controversy that divided the chemical community between atomists and equivalentists in the middle of the nineteenth century offer a more favorable space for individual choices? In view of the usual accounts of this famous controversy by historians of nineteenth-century chemistry, the situation would seem hopeless. It is usually assumed that the word "atom" was banished from chemistry in the wake of Dumas's disappointment with Avogadro's hypothesis. This standard view is based on Dumas's dramatic lecture delivered at the Collège de France in 1836 in which he said "If I had my way, I should erase the word 'atom' from science, in the firm belief that it goes beyond the realm of experiment; and never in chemistry must we go beyond the realm of experiment."[86] Indeed Dumas was influential enough: French chemists rejected the system of atomic weights and adopted equivalent weights, which were supposedly theory-free since they did not imply any commitment to a speculative theory of indivisible elementary particles.

The shift from atoms to equivalents is usually described as a retreat and attributed to two major national features. First, the overarching influence of Auguste Comte's positivism in France is said to have encouraged a prejudice against all hypotheses and theories about the structure of matter while encouraging a narrow Baconianism. Second, the centralized and mandarin organization of science in France, which allowed chemists like Dumas to accumulate various teaching positions in Paris while gaining political power, is said to have encouraged authoritarianism and consequently conservatism. The disastrous effects of the conjunction of this philosophical influence and institutional context is illustrated by Marcellin Berthelot in the second half of the nineteenth century. A staunch opponent of atomism, he became powerful enough to control the French educational system and to ban atomic notation and structural formulas from French teaching until his death in 1906.[87] In this scenario teachers and textbook authors had no choice but to adopt the equivalentist language imposed both by scientific authority and political power. They are portrayed as compliant servants or devoted followers of their mandarin academic chiefs, following their changing views on atomic theory that were supposedly imposed by syllabus control. Whereas the 1828 official syllabus, establishing the contents of scientific courses at the collèges royaux, included for the first time an explicit reference to atomic theory, the next official syllabus for the baccaluréat-ès-sciences, published in 1837—just one year after Dumas's famous lectures at the Collège de France—included a chapter on "proportional numbers" but none on atomic theory.[88]

This interpretation can certainly be supported by a quick glimpse at the forewords of many textbooks published in the middle of the nineteenth century. There one can find many anti-metaphysical claims: all speculative hypotheses should be avoided, only firmly established statements should be exposed to young pupils, and so on. In the name of a didactic imperative, many textbook writers favored a fetishist cult of matters-of-fact. Pelouze and Frémy, for instance, explained their choice in the following terms: "It is mainly a teaching book that we intended to write. It is thus conceivable that we had to admit only what can be called the most positive and verified part of science, namely the facts, and to reject what is only conjecture."[89] However, such statements—spreading the mythical image of experimental knowledge uncontaminated by hypotheses—were mainly rhetorical stances. A closer examination of the contents of a large number of textbooks over several decades invites revision of the standard account of nineteenth-century chemical atomism.

To begin with, French textbooks quickly adopted the atomic theory introduced by Dalton in the early nineteenth century and made increasing use of atomic language for describing chemical reactions. In fact chemical reactions had been described in molecular terms long before Dalton's atomic theory. The chapters on affinity forces, written in the eighteenth century, employed the words "integrant molecules" and "constituent molecules." Thus, unsurprisingly, Daltonian "physical" atoms were not regarded as a novelty by French chemistry textbook authors, who superimposed Daltonian atoms upon the traditional corpuscularism inherited from eighteenth-century chemistry in the first chapters of their books. The problem was not the physical existence of atoms, which was taken for granted, but rather how to know the number of atoms that combined in a chemical compound. Thenard expressed it as follows in 1827: "It seems undoubtedly demonstrated that all combinations proceed atom by atom and that they ordinarily take place between some of them. But how many? This is what we cannot say."[90]

The second question—how many atoms were in a compound—was closely related to the determination of atomic weights and its consequences in chemical formulas.[91] It forms what Alan Rocke calls "chemical atomism." Orfila and Thenard, for example, regarded atomic weights and the laws of chemical proportions as a useful tool for chemical analysis. Consequently they introduced these topics in their books as early as the 1810s. At the same time, as they recognized the various problems related to the determination of atomic weights, they gradually introduced the new methods derived from Dulong and Petit's law, Mitscherlich's isomorphism, and Avogadro-Ampère's hypothesis. Later in the 1820s, Berzelius's formulas reinvigorated atomism in French chemistry textbooks. Berzelian formulas were employed in order to convey chemical binary composition, to explain chemical reactions, and to classify chemical substances.[92] As a result, atoms gained space not only in the first introductory chapters but also in the chapters describing chemical properties of bodies, that is, in the most important part of nineteenth-century chemistry textbooks. Moreover, for the first time, a sharp distinction between equivalent and atomic weights was introduced in textbooks. While these words were employed with almost the same meaning as in the first editions, now separate tables of equivalents and atomic weights were included in Orfila's and Thenard's textbooks. Thus atomism was well established in textbooks by the mid 1830s, so that it deserved a full chapter in many textbooks.

Second, it is true that in the late 1830s and the early 1840s a significant number of French chemists eliminated the word "atom" from their textbooks. But did this mean the banishment of "atomic theory"? A glance at textbooks published during that period offers a more complex panorama. The first chapters still conveyed a picture of chemical reactions in terms of "molecules" (or "atoms") under the influence of chemical affinity forces. Afterwards, they included several chapters on "proportional numbers," "equivalent weights," or, in some cases, even under the title of "atomic theory." There were, however, substantial changes, which might be illustrated by paying attention to several editions of Mateu Orfila's textbook, whose seventh edition appeared in 1843. In that edition, Orfila erased the chapter on atomic theory, which had been introduced in the mid 1830s. He dramatically reduced the number of pages of his chapter on laws of chemical composition and on equivalents. Entire paragraphs were removed, such as those dealing with Gay-Lussac's law and its application to chemical calculations,[93] or with the advantages of equivalent weights in chemistry.[94] The introduction was reduced from 35 pages to six.[95] Orfila retained only one table with equivalent weights, without even mentioning that they differed from atomic weights. Finally, he included a brief description of Berzelian formulas and made a more extensive use of them than in previous editions. However, Orfila pointed out that these symbols should not be confused with "what is called atomic theory," "an hypothesis" with which he claimed he would never deal.[96] In the descriptive chapters, the paragraphs on chemical composition were rewritten in order to use exclusively chemical equivalent weights and formulas.

These changes did not reveal any positivistic or anti-metaphysical bias, since Orfila and a number of other textbook writers still employed a corpuscularian approach in their textbooks. Chemical reactions were still described in terms of particles (whether called atoms or molecules) endowed with affinity forces. For instance, a very popular book published by A. Bouchardat in 1842, which went through three editions, assumed that bodies were made up of small parts that "could be named molecules, atoms or particles." Bouchardat distinguished two kinds of molecules that he called "atomes intégrants" and "atomes constituants."[97] Similar terms were used by Grosourdy (1838–39), Guérin (1840), and Favrot (1841), whose books were intended for medical and pharmaceutical students. However, Jean Lassaigne, a chemistry lecturer at the Alfort Veterinary School, continued using "molécules intégrantes" and "molécules constituantes" while he largely employed atomic theory in his textbook during the 1840s. In technology-oriented lectures at the Conservatoire des arts et métiers, Anselme Payen distinguished between "molécules intégrantes ou atomes physiques" and "molécules constituantes ou atomes chimiques" during the early 1830s.[98] In contrast, Jean Jacques Colin, chemistry lecturer at the military school of Saint-Cyr, preferred the word "molecule" and developed a theory of his own. In 1841, when he was writing up the third edition of his textbook on chemistry, Colin published a booklet titled *Elementary considerations about chemical proportions, equivalents and atoms, being an introduction to the study of chemistry*.[99] It was an attempt to write an introduction to chemistry similar to Liebig's *Introduction à l'étude de la chimie*, but more adapted to "French ideas." The main result of this adaptative effort was the replacement of the word "atom" by the word "molecule" in order to avoid self-contradictory expressions such as "half-atom" or "an atom and a half." Colin strongly claimed that "chemical phenomena take place between molecules," and he employed the term "molecular weight" instead of "atomic weight." While acknowledging the differences between equivalent and atomic weights, Colin argued that there was no real problem because it was easy to convert the former values into the latter by simple arithmetic operations. In any case, he employed atomistic formulas in several chapters of his 1845 textbook.[100] In short, textbook writers followed the general trend of skepticism about calculations of the number of atoms in molecules, but they did not advocate agnosticism about the corpuscular structure of matter.

Rather than a "retreat" from atoms to equivalents, these examples show a wide spectrum of uses of the notions of "atoms" and "molecules." Rather than choose between two alternative matter theories, textbook writers appropriated some elements of atomic theory in their own rather creative ways. As a result, a broad range of situations could be found during the late 1830s and the early 1840s. Sometimes "atom" and "molecule" were treated as synonyms or quasi-synonyms, whereas Orfila preferred "atoms" in the early decades and "molecules" in the 1840s. It would be difficult to account for such changes by invoking any positivistic or anti-metaphysical tendency, since corpuscularian images still underlay the description of chemical reactions. It would be even more difficult to invoke an authoritarian order coming from top officials when there was such a striking lack of discipline in the use of the basic concepts.

Third, after the first international conference of chemists (held in Karlsruhe in 1860) prompted a general adoption of atomic weights and structural formulas in Europe, France (where Berthelot reigned supreme in the Academy of Sciences) was the last fortress of equivalentism. Yet there were committed atomists gathered around Adolphe Wurtz, an Alsatian chemist and professor at the Faculty of Medicine, who established a kind of research school on the model of Liebig's research school in Giessen. While they had to publish their research papers in the official language of equivalents, a number of French atomists took the opportunity to write textbooks to spread their atomistic convictions. Wurtz himself did not conceal his proselytic intentions when he published the second edition of his *Leçons élémentaires de chimie moderne* in 1871.[101] Simultaneously his disciple Alfred Naquet published a textbook titled *Principes de chimie fondée sur les théories modernes*. According to its publisher, the entire press run of Naquet's textbook sold out in a year and a half, and the book was translated into English, German, and Russian.[102] In the 1870s, Edouard Grimaux published a booklet dedicated entirely to the atomic theory, in addition to delivering lectures on the same topic at the Ecole polytechnique.[103] Paul Schützenberger, another student of Wurtz who became a professor at the Collège de France, opened his monumental *Traité de chimie générale* with words of revenge against Dumas's famous banishment of atoms. Thus, despite their usually uncontroversial character, textbooks did not remain outside the theoretical controversy about chemical atomism. Rather, they provided spaces of freedom for committed atomists who could not use the language of their choice in their research publications.

Conclusions

The emergence of textbooks as a distinctive genre has been analyzed in this essay as a negotiated process involving four main actors: the captive public of students, the authors, the publishers, and the French government. All of them cooperated to stabilize the concept of textbooks as material and commercial objects transmitting scientific knowledge for didactic purposes. Given their respective natures and functions, each mediated between the others. The public, which was the raison d'être of the whole enterprise, was only a virtual actor, since the ideal public defined by authors and publishers differed from the students who actually made use of textbooks. The French government defined the rules of the game, at least for primary- and secondary-school textbooks. The publishers defended the commercial interests of their private companies while negotiating with "public instruction." The authors were the only individual actors. In the beginning of the nineteenth century they derived their authority from their own scientific achievements, guaranteeing the validity of their claims by themselves. By contrast, in the middle of the nineteenth century the reliability of their writings derived from a chemical community represented by a few illustrious names and titles of publications. Their authority mainly relied on their teaching experience in a specific institution for a specific audience. Remarkably, the chemical community was never directly involved in the enterprise, since authors did not necessarily represent it. Yet it was always present behind the scenes, providing validation for scientific statements and exercising political power through some of its leaders.

The examples analyzed above show to what extent writing a textbook remained a creative activity. First, all didactic exposition of a science requires selecting and defining items and then organizing them into a coherent discourse. Second, even when the official syllabus prescribed the contents, it only provided the table of contents; the authors had to supply their own chemical narrative. The fact that we found a diversity of expositions of chemistry in the same period with very different views even of the basic concepts of the discipline means that there was no orthodoxy. Even in the French institutional framework that favored dogmas, chemical textbooks never became mere catechisms. Although textbooks were presented by their authors and publishers as spaces devoid of personal opinions and public controversies, they retained a degree of originality since they had to make decisions about ongoing debates. In fact, from a more pragmatic perspective, originality was no exception. Rather, it was the general rule—especially because textbooks had to claim originality either by addressing new audiences or by adopting novel didactic approaches in order to succeed in the market.

Textbooks no longer can be viewed as dogmatic and conservative vehicles of normal science. On the one hand, they are windows revealing new actors in the history of science: audiences, publishers, printers, and the silent crowd of unknown authors participated in the construction of science. On the other hand, this window sheds new light on the relation between teaching and research practices: textbooks played an important role in discipline-building and in creating theories. The price to be paid for opening these new avenues for the history of science is to study textbooks as objects of research for their own sake. The window glass is not transparent. Textbooks are intrinsically complex because of their multiple identities. As material objects, they are one of the various "paper tools" employed in many scientific practices. As commercial items, they are subjected to the constraints of the market. As educational tools, they are shaped and reshaped by local or national traditions and their ethnic, religious, and political roots. Textbooks can also be considered instruments of professionalization and mediators between scientific communities and the society at large. For all these reasons, textbooks offer historians a rich resource for studying the production of new scientific knowledge and new generations of scientific practitioners.

Notes

1. John H. Brooke, "Introduction: The study of chemical textbooks," in *Communicating Chemistry: Textbooks and their Audiences, 1789–1939*, ed. Anders Lundgren and Bernadette Bensaude-Vincent (Science History Publications, 2000), 1–18, on 1.

2. See Bernadette Bensaude-Vincent, "Mendeleev's periodic system of chemical elements," *British Journal for the History of Science* 19 (1986): 3–17; Nathan M. Brooks, "Dimitrii L. Mendeleev's *Principles of Chemistry* and the periodic law of the elements," in Lundgren and Bensaude-Vincent, *Communicating Chemistry*, 295–311; Michael D. Gordin, The Ordered Society and Its Enemies: D.I. Mendeleev and the Russian Empire, 1861–1905 (PhD dissertation, Harvard University, 2001), chapter 2.

3. Owen Hannaway, *The Chemists and the Word: The Didactic Origins of Chemistry* (Johns Hopkins University Press, 1975).

4. These and other questions were discussed in a workshop on "Chemical textbooks and their audiences" as part of a larger European program on the "Evolution of chemistry (1789–1939)." The workshop, which was held in Uppsala in 1996 with contributions from all over Europe, revealed a wide variety of textbook traditions with distinct national characteristics. The proceedings were published in Lundgren and Bensaude-Vincent, *Communicating Chemistry*.

5. Auguste Comte, *Cours de philosophie positive* (Hermann, 1975 [1830]), 2nd Leçon, volume 1, 50–51.

6. Gaston Bachelard, *La formation de l'esprit scientifique* (Vrin, 1972 [1938]), 24–28.

7. Thomas Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, 1962); idem, *The Essential Tension* (University of Chicago Press, 1977).

8. Kathryn Olesko, *Physics as a Calling: Discipline and Practice in the Königsberg Seminar for Physics* (Cornell University Press, 1991), 15–16.

9. On the emergence of popular science as an editorial genre in various national contexts, see Bernadette Bensaude-Vincent and Anne Rasmussen, *La science populaire dans la presse et l'edition: XIXe et XXe siècles* (CNRS, 1997). On encyclopedias, see Richard Yeo, *Encyclopaedic Visions: Scientific Dictionaries and Enlightenment Culture* (Cambridge University Press, 2001). Another interesting study on an early-modern genre of scientific literature is provided by William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton University Press, 1994).

10. Thomas H. Broman, "J. C. Reil and the 'journalization' of physiology," in *The Literary Structure of Scientific Argument*, ed. Peter Dear (University of Pennsylvania Press, 1991), 13–72.

11. See James A. Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of* Vestiges of Natural History of Creation (University of Chicago Press, 2000), esp. chapter 2.

12. Alain Choppin, *Les Manuels Scolaires: Histoire et Actualité* (Hachette, 1992); idem, "L'Histoire des manuels scolaires: Une approche globale," *Histoire de l'éducation* 9 (1980): 1–25.

13. For a review of recent literature on chemistry in French education, see the bibliography quoted in Bernadette Bensaude-Vincent, Antonio García-Belmar, and José R. Bertomeu-Sánchez, *La Naissance d'une science des manuels (1789–1852)* (Editions des Archives Contemporaines, 2003).

14. For more information about chemistry in medical and pharmaceutical curricula, see José R. Bertomeu-Sánchez and Antonio García-Belmar, "Mateu Orfila's *Eléments de chimie médicale* and the debate about chemistry applied to medicine during the early XIXth century in France," *Ambix* 47 (2000): 1–28.

15. Janis Langins, "The decline of chemistry at the *École polytechnique* (1794–1805)," *Ambix* 28 (1981): 1–19; idem, *La République avait besoin de savants: Les débuts de l'École polytechnique* (Belin, 1987); Bruno Belhoste, Amy Dahan Dalmedico, and Antoine Picon, *La Formation polytechnicienne, 1794–1994* (Dunod, 1994); Bruno Belhoste, *La Formation d'une technocratie: L'Ecole polytechnique et ses elèves de la Révolution au Second Empire* (Belin, 2003).

16. Claudette Balpe, "L'enseignement des sciences physiques: Naissance d'un corps professoral (fin XVIIIe-fin XIXe siècle)," *Histoire de l'éducation* 73 (1997): 49–85.

17. See Bertomeu-Sánchez and García-Belmar, "Mateu Orfila's *Eléments*."

18. J. Tyrat, *Nouveau manuel complet et méthodique des aspirants au Baccalauréat ès Sciences* (J. Delalaine, 1837).

19. During the 1830s and the 1840s, the term "manuel" was associated with texts that reduced the content of a chemistry course to a series of basic notions summarized in brief paragraphs so that students would learn them by heart and repeat them in the exams. These and other distortions introduced by the Baccalauréat in teaching methods were criticized by chemistry teachers and authors who considered the manuals to be the epitome of vicious educative methods.

20. Thérèse Charmasson, Anne-Marie Lelorrain, and Yannick Ripa, *L'Enseignement technique de la Révolution à nos jours* (Economica–Institut National de Recherche Pédagogique, 1987).

21. J. P. L. Girardin, *Leçon de chimie élémentaire, faites le dimanche à l'Ecole municipale de Rouen* (Rouvier, 1836–37); J. B. Dumas, *Traité de chimie appliquée aux arts* (Béchet jeune, 1828–1846).

22. A. Payen, *Cours de chimie élémentaire et industrielle destiné aux gens du monde* (Thomine, 1832).

23. Dumas, *Traité de chimie appliquée aux arts*, volume 1, viii.

24. F. M. J. Malaguti, *Leçons élémentaires de chimie* (Dezobry et E. Magdeleine, 1852), volume 1, préface.

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25. Balpe, "L'enseignement des sciences physiques."

26. Choppin, *Les Manuels scolaires*; idem, "Le cadre législatif et réglamentaire des manuels scolaires, I: De la Révolution à 1939," *Histoire de l'éducation* 29 (1986): 21–58; Alain Choppin and Martine Clinkspoor, *Les Manuels scolaires en France*, volume 4, *Textes officiels* (Institut National de Recherche Pédagogique, 1993).

27. The use of an "official textbook" as an instrument for educational, political, ideological, or religious control has been a common practice used in many different contexts and periods. See Karl Hall's essay in this volume, in which he refers to textbooks in the post-revolutionary Soviet Union.

28. See *Travail de la Commission chargée pour les mathématiques de désigner les livres classiques à l'usage de tous les lycées*, as quoted in Bruno Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, *1789–1914* (Institut National de Recherche Pédagogique, 1995), 78–80.

29. Ibid., 83–86.

30. *Règlement des études des lycées et collèges*, September 28, 1814, in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 88–90.

31. Bruno Belhoste, "Les caractères généraux de l'enseignement secondaire scientifique de la fin de l'Ancien Régime à la première guerre mondiale," *Histoire de l'éducation* 41 (1989): 3–45, on 34–35; idem, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 103.

32. Valérie Tesniere, "L'édition universitaire," in *Histoire de l'édition française*, ed. Henri Jean Martin and Roger Chartier (Promodis, 1983–1986), volume 3, 221–222; F. Barbier, "Une production multipliée," in ibid; Y. Mollier, "Histoire de la lecture, histoire de l'édition," in *Histoire de la lecture: Un bilan des recherches*, ed. Roger Chartier (Institut Mémoires de l'Edition Contemporaine, 1995).

33. Thomas Thomson, *Système de chimie* (Veuve Bernard, 1809).

34. See Secord, *Victorian Sensation*, chapter 4, for an outstanding study of the role of publishers in marketing a popular scientific text in nineteenth-century Britain.

35. Contract signed by Thenard, Dumas, and Bechet in Paris, April 30, 1849 (folder "Thenard," Archives de l'Académie des Sciences, Paris).

36. Dumas to Liebig, November or December 1831, as quoted in Alan Rocke, *Nationalizing Science: Adolphe Wurtz and the Battle for French Chemistry* (MIT Press, 2001), 56–57. Dumas complained about his "place de 2000 francs pour tout potage."

37. M. G. Chapel d'Espinasoux, "La Jeunesse d'Orfila: Fragment d'une autobiographie inédite publié par . . . ," *Revue hebdomadaire* 22 (1914): 615–634, and 23 (1914): 86–113; quotation on 97.

38. Archives Nationales de France (Paris), F17/20540.

39. Gay-Lussac's total salary was 45,400 francs at the beginning of the 1830s. See Maurice Crosland, *Gay-Lussac, 1778–1850* (Belin, 1991), 318–319. On "cumul" see also Rocke, *Nationalizing Science*, passim.

40. L. J. Thenard, *Traité de chimie élémentaire, théorique et pratique* (Crochard, 1813–1816), 4 volumes, in volume 1, ii–iii.

41. For an excellent discussion of how engraving techniques shaped a scientific discipline and teaching, see Klaus Hentschel, *Mapping the Spectrum: Techniques of Visual Representation in Research and Teaching* (Oxford University Press, 2002).

42. Andrew Warwick's study of mid-nineteenth-century mathematical education in Cambridge, England offers an additional example of how the boundaries between "original scientific research" and education are extremely diffuse, in constant transformation; the flow of knowledge between research and teaching is far from unidirectional. According to Warwick's study, original research results in mathematical physics were often announced as assigned problems on the Cambridge Mathematics Tripos exam. See Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (University of Chicago Press, 2003).

43. For a broader discussion of this topic and additional bibliography see José-Rámon Bertomeu-Sánchez, Antonio García-Belmar, and Bernadette Bensaude-Vincent, "Looking for an order of things: Textbooks and classifications in nineteenth century France," *Ambix* 49 (2002): 227–251.

44. A. Baume, *Chymie éxpérimentale et raisonnée* (P. F. Didot le jeune, 1773), volume 1, xii–xiv; quotation on xiv.

45. Piere-Joseph Macquer, *Elémens de chymie théorique* (J.T. Hérissant, 1753), xvi–xvii.

46. Antoine-François Fourcroy, *Système des connaisances chimiques* (Baudouin, 1800), volume 1, xxxiii–xxxv.

47. Bachelard, *La Formation de l'esprit scientifique*, 29–39.

48. Bernadette Bensaude-Vincent, "A view of the chemical revolution through contemporary textbooks: Lavoisier, Fourcroy, and Chaptal," *British Journal for the History of Science* 23 (1990): 435–460.

49. Thenard, *Traité de chimie élémentaire*, volume 1, i–ii.

50. See, for instance, Berzelius's criticisms against the order from simple to complex in J. J. Berzelius, *Traité de chimie* (Firmin-Didot, 1845–1850), volume 1, 2. See also Jean Louis Lassaigne, *Abrégé élémentaire de chimie* (Bechet jeune, 1829), volume 1, 69.

51. See, for instance, M. J. B. Orfila, *Elémens de chimie médicale* (Crochard, 1817); J. S. E. Julia de Fontenelle, *Manuel de chimie médicale* (Béchet, 1824); Lassaigne, *Abrégé élémentaire de chimie*. Thenard's metal classification was employed even in the early twentieth century in Troost's popular chemistry textbook: cf. Louis Troost, *Traité élémentaire de chimie*, eighth edition (G. Masson, 1885), 397–399; ibid., fifteenth edition (G. Masson, 1910), 382–384. For a description of Thenard's classification, see J. R. Bertomeu-Sánchez and A. García-Belmar, "Mateu Orfila y las clasificaciones químicas," *Cronos* 2 (2003): 3–35; Bertomeu-Sánchez, García-Belmar, and Bensaude-Vincent, "Looking for an order of things."

52. Ferdinand Hoefer, *Nomenclature et classifications chimique* (J. B. Baillière, 1845), 55.

D. KAISER (ed.), Pedagogy and the Practice of Science: Historical and Contemporary Perspectives, Boston, MIT, 219-253.

53. For a discussion of these issues, see José-Ramón Bertomeu-Sánchez and Antonio García-Belmar, "Mateu Orfila y las clasificaciones químicas," *Cronos* 2 (1999): 3–35.

54. A. M. Ampère, "Essai d'une classification naturelle pour les corps simples," *Annales de Chimie* 1 (1816): 295–308; 373–394;1–32; 105–125; quotation on 296. On Ampère's earlier drafts of his classification, see C. L. Dowland-Pillinguer, "A Chemist Full of Bold and Ingenious Ideas": The Chemical Philosophy of A.M. Ampère (1775–1836) (PhD dissertation, Cambridge University, 1988). For a presentation of the dilemma between artificial and natural classification see Bertomeu-Sánchez et al., "Looking for an order of things."

55. Ampère, "Essai d'une classification naturelle," 297.

56. Ibid.: "deux corps placés aux deux extrémités de la chaîne formée par tous les autres se rapprochent et s'unissent mutuellement par des caractères communs."

57. Ibid., 120–125. For Jussieu's ideas on continuity and classification in natural history, see Peter F. Stevens, *The Development of Biological Systematics: Antoine-Laurent de Jussieu, Nature, and the Natural System* (Columbia University Press, 1994). For a recent review of the topic, see *Spaces of Classification*, ed. Ursula Klein (Max-Planck-Institut for Wissenschaftsgeschichte preprint, 2003).

58. Hoefer, *Nomenclature et classifications chimique*.

59. According to his biographer, Gay-Lussac became a "powerful patron of Despretz during all the phases of his academic life": Crosland, *Gay-Lussac, 1778–1850*, 344–345. Cf. *Discours de M. Becquerel prononcé aux funérailles de M. Despretz . . . Le mardi 17 Mars 1863* (Firmin Didot, 1863).

60. C. M.Despretz, *Elémens de chimie théorique et pratique* (Méquignon-Marvis, 1829–30), volume 1, 1.

61. Ibid., volume 1, iv.

62. The "chromoïdes" group was closely similar to Thenard's fourth group. Cf. Thenard, *Traité de chimie élémentaire*, fifth edition (Crochard, 1827), volume 1, 320–322. The only exception was arsenic, which Thenard placed in the non-metallic group. Moreover, except for zirconium, the "alluminoïdes" group was identical to Thenard's first group.

63. Ibid.

64. "Programme du cours des sciences physiques pour les élèves des deux années de philosophie, 1 avril 1828," in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 115–121.

65. "Programme bac-ès-sciences mathématiques et physiques, 3 février 1837," in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 139–147. The program for chemistry is in ibid., 142–144.

66. "14 Juillet 1840, Questions de mathématiques et de physique au baccalauréat ès lettres," in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 152–161; "Questions de physique et de chimie," in ibid., 156–159. See in particular question 40: "Exposer les propriétés qui distinguent l'hydrogène, le carbone, le phosphore, le soufre, le chlore, l'iode. 24 février 1843.

Programmes de physique et de chimie en classe de philosophie," in ibid., 194–198 (chemistry on 197–198).

67. "30 août 1852, Nouveaux programmes de l'enseignement scientique," in ibid., 273–301, on 276–277 and 294–296.

68. J. B. Dumas, "Mémoire sur quelques points de la théorie atomique," *Annales de Chimie et de Physique* 33 (1826): 337–391, on 340. In the 1820s, Dumas published his studies on the "atomic volume," which he calculated as the ratio between atomic weight and density. See A. Le Royer and J. B. Dumas, "Essai sur le volume de l'atome des corps," *Journal de Physique de Chimie et de Histoire Naturelle* 92 (1824): 402–411. See also T. M. Cole, "Early atomic specultations of Marc Antonie Gaudin: Avogradro's hypothesis and the periodic system," *Isis* 66 (1975): 335–336. On Dumas's other works on chemical classification see John Van Spronsen, *The Periodic System of the Chemical Elements: A History of the First Hundred Years* (Elsevier, 1969), 74–75 and 85–87.

69. Dumas, *Traité de chimie appliquée aux arts*, volume 1, lxxivv. The classification was: 1st genre: Hydrogène; 2nd genre: F, Cl, Br, I; 3rd genre: Se, S, Appendice: O; 4th genre: P, As, Appendice: N; 5th genre: B, Si, Appendice.

70. Alexandre Edouard Baudrimont, *Introduction à l'étude de la chimie par la théorie atomique* (Colas, 1833); idem, *Traité de chimie générale et expériméntale* (J.-B. Ballière, 1844–1846).

71. Baudrimont, *Introduction*, 53–54.

72. Baudrimont, *Traité de chimie générale et expériméntale*, volume 1, 297. A similar approach had been discussed by Baudrimont in his *Traité élémentaire d'histoire naturelle* (H. Cousin, 1839), 47.

73. Thenard, *Traité de chimie élémentaire*, sixth edition (Crochard, 1834–1836), volume 5, 443.

74. Ibid., volume 5, 517–518.

75. Ferdinand Hoefer, *Eléments de chimie minérale* (Dezobry et E. Magdeleine, 1841), 45. He compared this chemical dichotomy with the old botanic groups: arbres vs. herbes.

76. Ibid., 5. Thenard's classification "quoique ingénieuse, est incomplète; et commence à être généralement abandonnée."

77. V. Regnault, "Recherches relatives à l'action de la vapeur d'eau à une haute température sur les métaux et sur les sulfures métalliques: Essai d'une nouvelle classification des métaux d'après leur degré d'oxidabilité," *Annales de Chimie* 62 (1836): 337–388.

78. Dumas, *Traité de chimie appliquée aux arts*, volume 2 (1830), 39–42. Dumas mentioned a "first family" with "two sections": 1: potassium, sodium, and lithium; and 2: barium, strontium, and calcium.

79. Ibid., volume 2, 67–68. Dumas discussed his classification in a chapter on "the action of oxygen on metals," and he even mentioned that his six sections were "borrowed from M. Thenard."

80. C. Favrot, *Traité élémentaire de physique, chimie, toxicologie et pharmacie* (Béchet jeune et Labé, 1841), 361.

81. Alphonse Dupasquier, *Traité élémentaire de chimie industrielle* (C.Savy jeune, 1844). Dupasquier died in 1848, and the second volume was not published. See Amédée Bonet, *Eloge d'Alphonse Dupasquie* (Imprimerie de Léon Boitel, 1849), 29–30.

82. Dupasquier, *Traité élémentaire de chimie industrielle*, volume 1, 60.

83. Ibid., volume 1, 65–66.

84. "30 août 1852, Nouveaux programmes de l'enseignement scientique," in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 273–301, on 276–277 and 294–296.

85. L. Nekoval-Chikhaoui, *Diffusion de la classification périodique de Mendeleiev en France entre 1869 et 1934* (Thèse Université de Paris IX, 1994), 85. The author claimed that many textbook writers affirmed the adoption of "la classification de Dumas": 1: F, Cl, Br, I; 2: O, S, Se, Te; 3: N, P, As; and 4: C, Si, B.

86. Jean Baptiste Dumas, *Leçons sur la philosophie chimique* (Cultures et civilisations reprint, 1972 [1837]), 246; quotation translated by Robert Fox, *The Caloric Theory of Gases from Lavoisier to Regnault* (Clarendon, 1971), 291.

87. For reviews of the recent literature, see Rocke, *Nationalizing Science*; José-Ramón Bertomeu-Sánchez and Antonio García-Belmar, "Atoms in French chemistry textbooks during the first half of the nineteenth-century," *Nuncius* 19 (2004), no. 1: 77–119.

88. "Programme du cours des sciences physiques pour les élèves des deux années de philosophie, 1 avril 1828," in Belhoste, *Les Sciences dans l'enseignement secondaire en France*, volume 1, 115–121; "Programme des baccalauréats ès sciences mathématiques et ès sciences physiques, 3 février 1837," in ibid., 139–147: "lois suivant lesquelles les corps se combinent; nombres proportionnels."

89. J. Pelouze and E. Frémy, *Cours de chimie générale* (V. Masson, 1848), volume 1, 1.

90. Thenard, *Traité de chimie élémentaire*, fifth edition (1827), volume 1, 173–174.

91. For instance, following a simplified description of the case of water, 1 part of hydrogen reacts with 8 parts of oxygen to create 9 parts of water. The formula HO implies that oxygen has an atomic weight of 8 (taking hydrogen as having unit atomic weight), whereas assuming the formula H_2O implies 16 as the atomic weight for oxygen.

92. On the multiple meanings of Berzelian formulas as paper tools, see Ursula Klein, *Experiments, Models, Paper Tools: Cultures of Organic Chemistry in the Nineteenth Century* (Stanford University Press, 2003).

93. Cf. M. Orfila, *Elémens de chimie, appliquée à la mèdicine et aux arts*, sixth edition (Crochard, 1835–36), volume 1, 27–29; idem, *Elémens de chimie*, seventh edition (Fortin, Masson, et Cie, 1843), volume 1, 11–12.

94. Cf. M. Orfila, *Elémens de chimie*, sixth edition (1835–36), volume 1, 36–40; idem, *Elémens de chimie*, seventh edition (1843), volume 1, 14–16.

95. Cf. M. Orfila, *Elémens de chimie*, sixth edition (1835–36), volume 1, 23–58; idem, *Elémens de chimie*, seventh edition (1843), volume 1, 11–17.

96. M. Orfila, *Elémens de chimie*, seventh edition (1843), volume 1, 17.

97. A. Bouchardat, *Cours des sciences physiques* (G.Baillière, 1842), 2. The second edition appeared in 1845 and the third in 1848.

98. A. Payen, *Cours de chimie élémentaire et industrielle* (Thomine, 1832), volume 1, 50.

99. Jean-Jacques Colin, *Considérations élémentaires sur les proportions chimiques* (Chez Gauthier Laguionie, 1841).

100. Jean-Jacques Colin, *Cours de chimie*, third edition (Gaultier-Languionie, 1841), 24–25; ibid., fourth edition (1845), 23–24.

101. Adolphe Wurtz, *Leçons élémentaires de chimie moderne* (Masson, 1867–68), advertisement; ibid., second edition (1871).

102. Alfred Naquet, *Principes de chimie fondés sur les théories modernes* (F. Savy, 1865).

103. Edouard Grimaux, *Chimie inorganique élémentaire* (Victor Masson, 1874); idem, *Introduction à l'étude de la chimie, théories et notations chimiques* (Dunod, 1883).

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