6. A. L. Lavoisier, *Elements of Chemistry*, trans. R. Kerr, republication of the first edition of 1790, with new introduction by D. McKie, Dover, New York, 1965, p. 319.

7. A. Donovan, "Lavoisier and the Origins of Modern Chemistry," *Osiris*, **1988**, *4*, 214-231.

8. J. G. McEvoy, "Continuity and Discontinuity in the Chemical Revolution," *Osiris*, **1988**, *4*, 195-213.

9. P. S. du Pont to D. McKie, 15 July 1952, unpublished letter.

---

*Dr. A. Truman Schwartz is Professor of Chemistry at Macalester College, 1600 Grand Avenue, Saint Paul, MN 55105.* *His original talk was accompanied by a set of beautiful color slides of Lavoisier's apparatus taken at the Musée des Techniques, Conservatoire National des Arts et Métre in Paris, which we are unfortunately unable to reproduce within the limits of the Bulletin's current format.*

---

## BOOKS OF THE CHEMICAL REVOLUTION

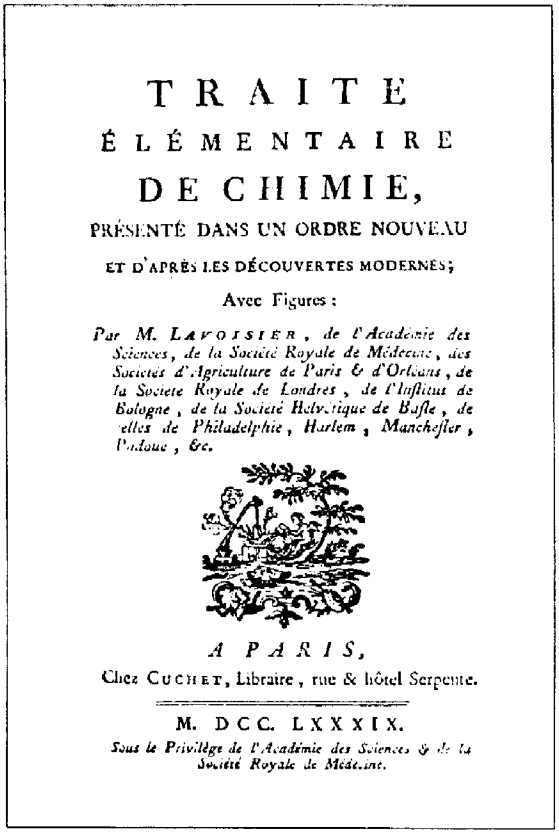
### Part III: Traité Élémentaire de Chimie

*Ben B. Chastain, Samford University*

The revolution of modern chemistry was a process, not an event. There is no Bastille Day to point to as the seminal occurrence from which it grew. The fact that 1989 has been the year chosen for its bicentennial celebration is in no small part due to the publication in March 1789, in Paris, of the *Traité Élémentaire de Chimie* by Antoine Lavoisier. It is certainly the most widely known "book of the revolution". Professor Douglas McKie, among others, has claimed that Lavoisier's *Traité* did for chemistry what Newton's *Principia* had done for physics a century before (1).

Earlier papers in this series presented the *Méthode de Nomenclature Chimique* of 1787 as the lexicon of the revolution; and the third edition of Fourcroy's *Élémens d'Histoire Naturelle et de Chimie*, published in December 1788, as its first textbook (2). By the spring of 1789 the *Méthode* had already been translated into English and Spanish, and at least summarized in Italian; the earlier editions of the *Élémens* had also been widely disseminated, and the new material of the third edition had already appeared in English as well as French. These two books, then, were at work spreading the revolution when the *Traité* appeared on the scene. This paper will briefly discuss this third book, and its relationship to the previous two.

We should recall that Lavoisier's contribution to the 1787 *Méthode* consisted of the text of a paper which he had presented in April of that year to a public meeting of the French



TRAITE
ÉLÉMENTAIRE
DE CHIMIE,
PRÉSENTÉ DANS UN ORDRE NOUVEAU
ET D'APRÈS LES DÉCOUVERTES MODERNES;
Avec Figures :

Par M. LAVOISIER, de l'Académie des Sciences, de la Société Royale de Médecine, des Sociétés d'Agriculture de Paris & d'Orléans, de la Société Royale de Londres, de l'Institut de Bologne, de la Société Helvétique de Bâsle, de celles de Philadelphie, Harlem, Manchester, Padoue, &c.

A PARIS,
Chez CUCHET, Libraire, rue & hôtel Serpente.

M. DCC. LXXXIX.
Sous le Privilège de l'Académie des Sciences & de la Société Royale de Médecine.

Academy of Sciences. In it, he gave the background of the suggested reforms, and credited those in the past who had worked on nomenclature, including Macquer in France for his 1766 *Dictionnaire de Chimie*, Bergman in Sweden for his 1784 scheme for classifying and naming minerals, and especially Guyton de Morveau, whose 1782 paper formed the basis for the new system. Lavoisier praised Guyton for his willingness to sacrifice his own ideas and previous work to the present collaboration. He described the conferences of the four authors, conferences which ranged over the whole of chemistry as well as the metaphysics of language, as being quite free of personal considerations. The rest of the paper dealt mainly with the ideas of the Abbé Bonnot de Condillac on the importance of language, with quotes such as "We only reason well or reason badly in so far as our language is well or badly constructed ..." and "The progress of the sciences depends entirely on the progress of their languages".

According to the preface to the *Traité*, it was Lavoisier's intention only to "extend and explain" this paper on nomenclature when he began the work which grew into the *Traité Élémentaire de Chimie, presente dans un ordre nouveau et d'apres las decouvertes modernes* (3). His extension and explanation became a book which might be described as both a manifesto for the Chemical Revolution and a manual for new revolutionaries.

A manifesto is a public declaration, made by a person or

group claiming important status or taking important actions, which sets forth the reasons, motives, or objects of their claim. Indeed, Lavoisier had written in his notebooks in 1773 that his researches seemed "destined to bring about a revolution in physics and in chemistry", and perhaps the *Traité* can be seen as his public declaration that the revolution was taking place and the new chemistry was overthrowing the old. Especially in the Preface and in the first section of the book, he sets forth the motivation and approach which led to the revolution and details the steps taken to bring it about.

In the Preface we find this commentary on the "study and practice of the sciences" (pp. xvii-xviii):

> Imagination, which is ever wandering beyond the bounds of truth, joined to self-love and that self-confidence we are so apt to indulge, prompt us to draw conclusions which are not immediately derived from facts; so that we become in some measure interested in deceiving ourselves. Hence it is by no means to be wondered that, in the science of physics in general, men have often made suppositions, instead of forming conclusions. These suppositions, handed down from one age to another, acquire additional weight from the authorities by which they are supported, till at last they are received, even by men of genius, as fundamental truths. The only method of preventing such errors taking place, and of correcting them when formed, is to restrain and simplify our reasoning as much as possible ... We must trust to nothing but facts; these are presented to us by Nature, and cannot deceive ... I have imposed upon myself, as a law, never to advance but from what is known to what is unknown; never to form any conclusion which is not an immediate consequence necessarily flowing from observation and experiment ...

Here, then, is a basic principle of the approach to be taken in modern chemistry and a manifesto-like statement.

Parenthetically, let us note that in this same section he says:

> It ought to be considered that very little of chemistry can be learned in a first course, which is hardly sufficient to make the language of the science familiar to the ears, or the apparatus familiar to the eyes. It is almost impossible to become a chemist in less than three or four years of constant application.

And that's 200 years ago, with no remedial work or general liberal arts curriculum!

Another important principle of the new chemistry is also stated in the preface (p. xxiv):

> All that can be said upon the number and nature of elements is, in my opinion, confined to discussions entirely of a metaphysical nature ... If, by the term elements, we mean to express those simple and indivisible atoms of which matter is composed, it is extremely probable we know nothing at all about them; but, if we apply the term elements, or principles of bodies, to express our idea of the last point which analysis is capable of reaching, we must admit as elements all the substances into which we are capable, by any means, to reduce bodies by decomposition.

It is the application of this principle which leads to the "Table of Simple Substances" found at the beginning of the second part of the book (p. 175), frequently called the first list of the elements, and cited by Douglas McKie in his biography of Lavoisier as "the most revolutionary feature of the *Traité*."

One more quote from the preface, dealing with part one (pp. xxxiii-xxxiv):

> ... chemists will easily perceive that, in the first part of my work, I make very little use of any experiments but those which were made by myself: If at any time I have adopted, without acknowledgement, the experiments or the opinions of M. Berthollet, M. Fourcroy, M. de la Place, M. Monge, or, in general, of any of those whose principles are the same with my own, it is owing to this circumstance, that frequent intercourse, and the habit of communicating our ideas, our observations, and our way of thinking to each other, has established between us a sort of community of opinions, in which it is often difficult for every one to know his own.

This may have some bearing on the later insistence of Lavoisier that the new theory was his alone, and not that of "the French chemists" as was said by some (4).

The first part of the *Traité*, entitled "Of the Formation and Decomposition of Aeriform Fluids, - of the Combustion of Simple Bodies, and the Formation of Acids" is in effect a summary of the researches of Lavoisier (and perhaps some others) over the period 1773-1788, arranged in such an order "as shall render it most easy for beginners in the study of chemistry thoroughly to understand them" (p. xviii).

Antoine Laurent Lavoisier

It describes in detail many experiments which reveal the composition of the atmosphere, of water, and of acids and bases. In a chapter on vinous fermentation we find the first application of the law of conservation of matter to chemical changes (p. 130):

> We may lay it down as an incontestible axiom that, in all the operations of art and Nature, nothing is created; an equal quantity of matter exists both before and after the experiment; the quality and quantity of the elements remain precisely the same; and nothing takes place beyond changes and modifications in the combination of these elements. Upon this principle the whole art of performing chemical experiments depends ...

Later in the same chapter he points to a consequence of this principle, the chemical equation (p. 140):

> We may consider the substances submitted to fermentation, and the products resulting from that operation, as forming an algebraic equation; and, by successively supposing each of the elements in this equation unknown, we can calculate their values in succession, and thus verify our experiments by calculation, and our calculation by experiments reciprocally.

This first part, then, comprises the essentials of the new chemistry, and, taken with the preface, might be considered the manifesto of the revolution, in the words of the premier revolutionary.

The middle section of the *Traité*, entitled "Of the Combinations of Acids with Salifiable Bases, and of the Formation of Neutral Salts", contains little that is new, and in Lavoisier's own words "nothing which I can call my own". It is chiefly tables of the new nomenclature for salts, and the acids and bases from which they are made. Its most noted feature is the aforementioned "Table of Simple Substances" (p. 175). It is shorter than the corresponding table in the 1787 *Méthode*, lacking the list of organic radicals (which Lavoisier had decided were made of carbon and hydrogen.) It contains 33 items, 23 of which we still consider elements - 17 metals, oxygen, hydrogen, azote (nitrogen), sulphur, phosphorus, and charcoal (carbon). Also listed are light and caloric (heat), which Lavoisier still felt to be substances; three acid radicals - muriatic, fluoric, and boracic (derived from chlorine, fluorine, boron); and five "earthy substances" - lime, magnesia, barytes, argill (alumina), and silex. Once again the author cautions the reader (p. 177):

> ... these things we at present suppose simple may soon be found quite otherwise. All we dare venture to affirm of any substance is, that it must be considered as simple in the present state of our knowledge ... We may even presume that the earths must soon cease to be considered as simple bodies; they are the only bodies of the salifiable class which have no tendency to unite with oxygen; and I am much inclined to believe that this proceeds from their being already saturated with that element. If so, they will fall to be considered as compounds consisting of simple substances, perhaps metallic, oxydated to a certain degree.

He also notes that "the fixed alkalies, potash and soda, are omitted in the foregoing Table, because they are evidently compound substances, though we are ignorant as yet what are the elements they are composed of" (p. 178). This table, with its caveats, perhaps deserves to be regarded as the first list of the chemical elements.

The third section of the *Traité* is what I have chosen to call the manual of the revolution, instructions for do-it-yourself "new chemistry". Its title is "Description of the Instruments and Operations of Chemistry"; its purpose is explained in the Preface (p. xxxv):

> The method of performing experiments, and particularly those of modern chemistry, is not so generally known as it ought to be; and had I, in the different memoirs which I have presented to the Academy, been more particular in the details of the manipulations of my experiments, it is probable I should have made myself better understood, and the science might have made a more rapid progress.

He adds: "I need hardly mention that this part could not be borrowed from any other work, and that, in the principal articles it contains, I could not derive assistance from anything but the experiments which I have made myself."

The plates, originally drawn by Mme. Lavoisier, are beautifully detailed; comparison with some of the actual pieces of apparatus (which can still be seen at the Musée des Techniques in Paris) attest to their accuracy. One interested in doing so should have been able to construct such apparatus and reproduce the results given in the book. As aids to this end, appendices give various unit conversions, densities of several gases, and specific gravities for a large number of substances.

As has been pointed out by several writers, Lavoisier's *Traité* is really not a textbook for beginners in chemistry (4); its limited scope and research approach make it less valuable in that regard than Fourcroy's *Élémens* or others that came along - Chaptal's, for instance (5). Nevertheless, it was reprinted a number of times in France, and translated into many other languages. Its place, and its author's, in the history of chemistry are quite secure. It has been for these 200 years emblematic of the revolution of modern chemistry. But in promoting the spread of that revolution, it shares credit with at least two other influential volumes, and joins them on my "Revolutionary Bookshelf". There we find the lexicon of the revolution, its first textbook, and its manifesto/manual - worthy to be remembered and celebrated by chemists in this bicentennial year or, for that matter, in any other year.

**References and Notes**

1. D. McKie, *Antoine Lavoisier: Scientist, Economist, Social Reformer*, Schuman, NY, 1952; p. 274. This is one of the best "popular" biographies of Lavoisier in English.

2. B. Chastain, "Books of the Chemical Revolution", *Bull. Hist. Chem.*, **1989**, *3*, 7-11; and **1989**, *4*, 8-11.

3. A. Lavoisier, *Elements of Chemistry*, Dover, NY, 1965, p. xiii. This is an unabridged republication of the 1790 translation by Robert Kerr, originally published by Wm. Creech in Edinburgh. It contains a valuable introductory essay by Douglas McKie. It is still in print.

4. See R. Siegfried, "The Chemical Revolution in the History of Chemistry", *Osiris*, **1988**, *4*, 39.

5. J. A. Chaptal, *Élémens de Chimie*, Montpellier, 1790.

---

*Dr. Ben Chastain is Chairman of the Department of Chemistry of Samford University, Birmingham, AL 35229 and is interested in the great books of chemistry. This article completes his three-part series on the "Books of the Chemical Revolution."*

---

## THE INGENIOUS, LIVELY AND CELEBRATED MRS. FULHAME AND THE DYER'S HAND

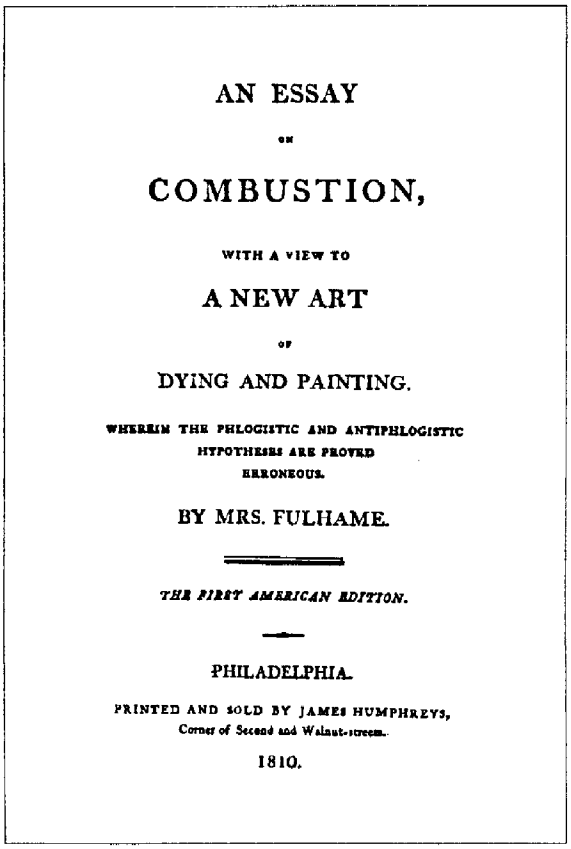
*Derek A. Davenport and Kathleen M. Ireland,*
*Purdue University*

Recent revisionist scholarship still allows that 1794 was a crucial year for both Antoine Lavoisier and Joseph Priestley (1). It was also a crucial year for the less often celebrated Mrs. Fulhame - the intermittent labors of close to 14 years culminated in the publication of her *Essay on Combustion with a view to a New Art of Dying and Painting wherein the Phlogistic and Antiphlogistic Hypotheses are Proved Erroneous* (2). The *Essay* was to prove Mrs. Fulhame's only publication and what little we know of her must be inferred from the idiosyncratic preface and from the few personal references in the body of the book. As with Shakespeare's sonnets and their elusive lady:

*My nature is subdued*
*To what it works in, like the dyer's hand;*
*Pity me then and wish I were renewed.*

Not that the book was to pass unnoticed. The normally ungenerous Count Rumford conceded (3):

This agrees perfectly with the results of similar experiments by the ingenious and lively Mrs. Fulhame. It was on reading her book that



AN ESSAY

ON

COMBUSTION,

WITH A VIEW TO

A NEW ART

OF

DYING AND PAINTING.

WHEREIN THE PHLOGISTIC AND ANTIPHLOGISTIC HYPOTHESES ARE PROVED ERRONEOUS.

BY MRS. FULHAME.

THE FIRST AMERICAN EDITION.

PHILADELPHIA.

PRINTED AND SOLD BY JAMES HUMPHREYS, Corner of Second and Walnut-streets.

1810.

First American edition of Mrs. Fulhame's book.

I was induced to engage in these investigations; and it was by her experiments that most of the foregoing experiments were suggested.

while the normally charitable Priestley grumped (4):

... her theory is fanciful, and fabulous, as the story of the phenix itself.

a quotation to which J. R. Partington added the even less charitable and quite gratuitous footnote (5):

The phoenix, it may be noted, was a fabulous bird regarded as sexless.

The *Essay* received several reviews in French journals, one, by Coindet, running to 27 pages with detailed chapter-by-chapter summaries (6). A German translation appeared in 1798 and, as we shall see, an American edition in 1810.

The genesis of the book is described in the preface:

The possibility of making cloths of gold, silver, and other metals by chymical processes, occurred to me in the year 1780; the project being mentioned to Doctor Fulhame and some friends, was deemed improbable. However, after some time, I had the satisfaction of realizing the idea in some degree by experiment.