16. F. L. Holmes, *Lavoisier and the Chemistry of Life*, University of Wisconsin, Madison, WI, 1985, pp. 160-167.
17. Reference 15, pp. 393-408.
18. Reference 16, pp. 116-118.
19. Ibid., pp. 180-182; and reference 15 pp. 394-398.
20. Reference 16, pp. 202-204, 208-210.
21. Ibid., pp. 211-219.
22. Ibid., pp. 224-236.

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INSTRUMENTS OF THE REVOLUTION: LAVOISIER'S APPARATUS

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The development of the new chemistry required the design and use of new apparatus. In this respect, Lavoisier's experimental *modus operandi* marks another departure from the procedures of his predecessors and contemporaries. In contrast, Joseph Priestley seems to have performed many of his experiments with conventional equipment - retorts, receivers, furnaces, and burning glasses. Indeed, the drawings of Priestley's equipment show something that looks like a common basin used as a pneumatic trough and ordinary wine glasses and jars used as his glassware. But Lavoisier's laboratory at the Arsenal of Paris was equipped with the products of some of Europe's finest instrument makers, much of it designed to the scientist's exacting specifications and constructed for a specific investigation (1).

A study of the instruments of Lavoisier's revolution is facilitated by the superb engravings that illustrate the *Traité Élémentaire de Chimie* and his other works. For the most part, they were based upon drawings made by Antoine's wife, Marie Paulze Lavoisier. This gifted woman's formal convent-based education had concluded shortly before her marriage, at the age of 13. Nevertheless, she played a major role in her husband's busy life - especially his scientific researches. She studied English and translated into French a number of important chemical works, including Kirwan's *Essay on Phlogiston* (1788). Following Antoine's death, she edited, published, and privately distributed his *Mémoires de Chimie* (1805) (2).

Mme. Lavoisier's natural talent for drawing, enhanced by her studies with David, are evident from her illustrations. Almost all the original sketches, drawings, and proofs have survived, so one can trace her method. She began with water-

Madame Lavoisier (Marie Anne Pierette Paulze) as a young girl.

color sketches and then copied these, in pencil, on squared paper corresponding in size to the desired plates. The pencil drawings were, in turn, transferred by stylus to the copper engraving plates. Like her husband, Mme. Lavoisier appears to have been a demanding perfectionist. Denis Duveen and Herbert Klickstein, in their bibliography of Lavoisier's works (3), report that a number of revisions were sometimes required before the proof warranted her stamp of approval - the word "Bonne" followed by her initials. It is also worth noting that Marie Lavoisier painted a portrait of Benjamin Franklin that greatly pleased the subject. Unfortunately, it is lost.

If nothing more than the plates to Lavoisier's works had survived, one could probably reconstruct his apparatus without much difficulty. But, somewhat surprisingly given the circumstances of his death, much of his equipment has actually been preserved. The Musée des Techniques of the Conservatoire National des Arts et Métiers has an extensive collection. Indeed, that rather dusty and sleepy institution is something of a sacred shrine for chemists. The museum, which includes a deconsecrated church, is an eclectic mixture of early airplanes and automobiles, clocks and watches, Jacquard looms, and a preliminary model of the Statue of Liberty. Its centerpiece is the Lavoisier exhibit.

In his biography of Lavoisier, Douglas McKie calls the laboratory at the Arsenal "remarkable." "Up to that time," he writes (4):

> ... there had been nothing to compare with it; and many years were to pass before such a collection of instruments, especially of precision instruments and chemical apparatus, would be put together again as the working tools of a laboratory - probably not until the rise of the

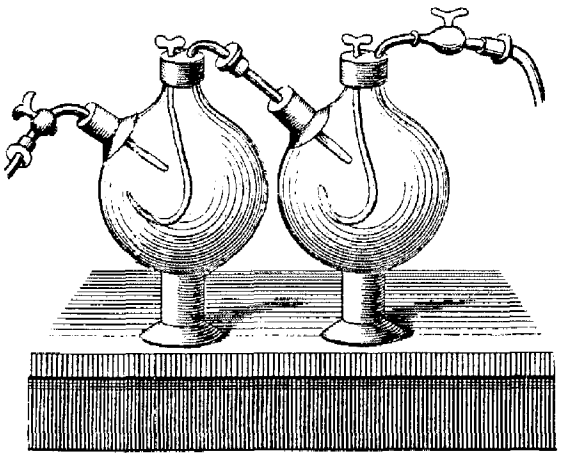
modern research institutions.

Maurice Daumas, in his studies of 18th century scientific apparatus, frequently comments on the state-of-the-art equipment made for and used by Lavoisier (5).

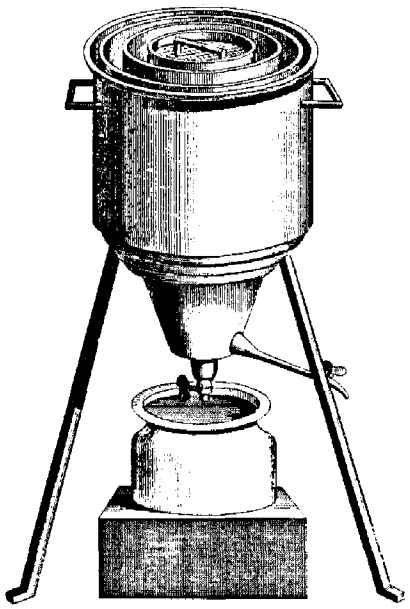
The fact that Lavoisier's inherited wealth and his income from the Ferme-Général and the Gunpowder Commission made him well-to-do is obvious from the care and craftsmanship devoted to the design and construction of his instruments. Many pieces were designed specifically for certain experiments, for example his calorimeters, gasometers, combustion bulbs and trains, and fermentation equipment (see figures in this article and on p. 25 and pp. 27-28). In his description of the gasometer, Lavoisier acknowledges the high costs associated with doing chemical research (6):

> In the present advanced state of chemistry, very expensive and complicated instruments are become indispensably necessary for ascertaining the analysis and synthesis of bodies with the requisite precision as to quantity and proportion; it is certainly proper to endeavor to simplify these, and to render them less costly; but this ought by no means to be attempted at the expense of their conveniency of application, and much less of their accuracy.

The reliance that Lavoisier placed on physical measurements and the apparatus necessary to make them supports Arthur Donovan's thesis that the great French scientist was attempting to establish a new, more scientific chemistry based upon the model of experimental physics (7). Quantitative experimentation was the means, but theoretical knowledge was the end. As John McEvoy and others have pointed out, Lavoisier worked and thought algebraically (8). His experiments and his logic were intellectually, if not always symbolically, based on equations. Hence the importance of reliable, accurate, and precise instruments.



Gas absorption bulbs belonging to a special apparatus for the combustion analysis of oils constructed for Lavoisier by Fortin in 1788. The bulbs are now in the Musée des Techniques, Conservatoire National des Arts et Métre in Paris.



The ice calorimeter used by Lavoisier and Laplace as pictured in the *Traité*.

Lavoisier's favorite instrument-makers were Nicolas Fortin and Pierre Mégnié (Mégnié the Younger), but McKie's 1952 inventory of 418 items lists apparatus made by 28 others, including Adams, Beringer, Chevalier, Ciceri, Delabarre, Le Maire, Ramsden, and Richer.

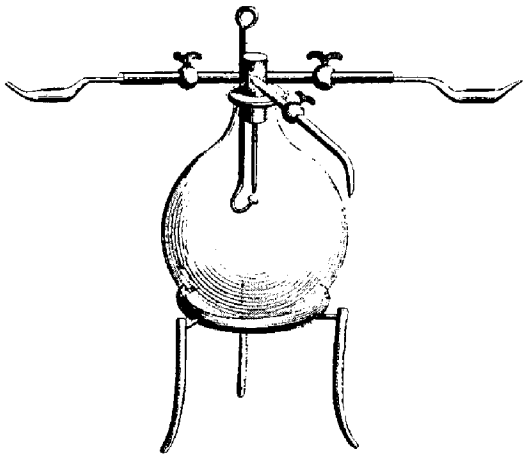
After Lavoisier's execution, his home at 243 Boulevard de la Madeleine de la Ville l' Evêque was visited by large numbers of representatives of the various commissions and committees on which Lavoisier had served. They were all eager to recover property belonging to these groups. A number of inventories were drawn up, and the Lavoisier bicentennial exhibit at the Palais de la Découverte included four. Two chemists, Nicholas Leblanc and Claude Louis Berthollet, began their inventory of the chemical apparatus on 15 June, but broke off shortly after Mme. Lavoisier was arrested on that day. They resumed their work in September, following her release in August. Altogether they listed over 13,000 items of chemical apparatus and specimens, valued at more than 7,000 livres. Included were 170 pounds of mercury and 60 pounds of mercuric oxide, valued at 2,030 livres. Jacques Charles (of hydrogen balloon fame), Fortin (the instrument maker), and Lenoir prepared an inventory of about 250 instruments and pieces of physical apparatus, including three balances (see figures on pp. 21-22), which were valued at 3,500 livres. An interesting footnote is that one of the inventories was attested to by Dr. Joseph Guillotin who, in 1784, had served with Lavoisier on the commission investigating mesmerism.

Lavoisier's apparatus, chemicals, books, papers, and furni-

ture, including his roll-top desk, were confiscated and divided among the École Centrale, the Museum of Natural History, and the Bureau of Mines. The fact that they were returned within less than a year probably saved them from being widely scattered and lost. Again, the records seem to have been remarkably thorough and the restoration essentially complete. For example, of the books taken from Lavoisier's country estate in Fréchines, only three volumes were missing. It is unfortunate that the republican government of France did not show comparable concern for preserving human resources, but, as Coffenhal supposedly said in delivering his verdict, "La République n'a pas besoin des savants."

The trail of Lavoisier's instruments breaks, at least for me, on their return to his widow. She, of course, survived her brief and rocky marriage to Count Rumford and lived until 1836. Since she and Antoine had no children, and since his only sibling died without issue at 15, Lavoisier's direct line came to an end. However, Lavoisier's effects were apparently passed on to members of Marie's family. The apparatus surfaces again in the 20th century in the possession of Madame la Comptesse de Chazelle of Champaissant in the department of Sarthe. She is identified as a descendant of Mme. Lavoisier and the owner of most of the books, papers, and apparatus exhibited in 1943 at the Palais de la Découverte to commemmorate the bicentennial of Lavoisier's birth. This was, of course, during the German occupation of France, but the catalogue suggests a carefully planned and complete exposition.

Many of the same pieces again appear on an inventory of 418 items belonging to Madame de Chazelles prepared in 1952 by Douglas McKie at the request of Pierre Samuel du Pont. This list, kindly provided to me by the Hagley Museum and Library of Wilmington, Delaware, includes, in addition to many of the major items shown earlier, many thermometers, barometers, weights, and pieces of electrical equipment. McKie concludes that several of the items, among them a plaster seal of the Royal Institution of Great Britain and two freemason's aprons, must have belonged to Rumford.



A combustion bulb with electrodes for studying the combination of hydrogen and oxygen under a constant flow of the reacting gases.

The inventory was undertaken preliminary to the purchase of the collection by du Pont for presentation to the Conservatoire National des Arts et Métiers. A letter from du Pont to McKie, dated 15 July 1952, reports that the final payment to Madame de Chazelle had just been sent. "This settlement," du Pont continues, "will, I believe, restore Madame's confidence and good humor." Alas, there is no elaboration of this intriguing morsel. The benefactor proves modest in his final paragraph (9):

> In some of the correspondence in regard to the collection, it has been intimated that it was proposed to confer upon me some recognition by the Legion of Honor or other society. This I feel is quite unnecessary, as the satisfaction in having the collection preserved in a safe place is quite sufficient award for me.

There is a fitting symmetry in the involvement of the du Pont family in seeing Lavoisier's apparatus delivered to the people of France. An ancestor of the benefactor, who also bore the name Pierre Samuel, was a close friend of Lavoisier. A widower, he unsuccessfully proposed marriage to Marie Lavoisier before he emigrated to America in 1800. With him went his two sons, Victor and Eleuthère Irénée. The latter had spent five years with Lavoisier at the Arsenal, helping with the research and learning the art and science of gunpowder manufacture. The success of the gunpowder factory E. I. du Pont founded on the banks of the Brandywine River in Wilmington, Delaware, suggests that he learned well. The revolution launched by Lavoisier's intelligence, insight, and instrumentation had come to the United States with the du Ponts.

References and Notes

1. The author wishes to thank Ms. Maureen O'Brien Quimby, Curator of Collections, and her colleagues at the Hagley Museum, Wilmington, Delaware, for supplying important documents, and Professor Mary Lou Wolsey, Department of French, College of St. Thomas, St. Paul, Minnesota, for assistance in the translation and interpretation of certain passages.

2. For details of Madame Lavoisier's life, see D. I. Duveen, "Madame Lavoisier", *Chymia*, **1953**, *4*, 12-29.

3. D. I. Duveen and H. S. Klickstein, *A Bibliography of the Works of Antoine Laurent Lavoisier, 1743-1794*, Dawson & Sons, Ltd. and E. Weil, London, 1954, p. 158.

4. D. McKie, *Antoine Lavoisier*, Schuman, New York, 1952, pp. 258-259.

5. See for example, M. Daumas, *Lavoisier: Théoricien et Expérimentateur*, Presses Universitaires de France, Paris, 1955, and "Les Appareils d'Experimentation de Lavoisier," *Chymia*, **1950**, *3*, 45-62.

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.

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BOOKS OF THE CHEMICAL REVOLUTION

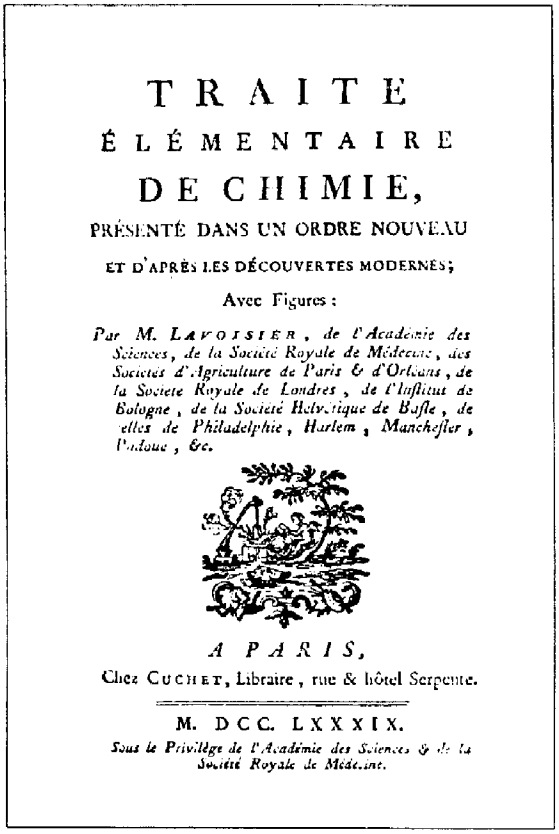
Part III: Traité Élémentaire de Chimie

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,
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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