

THE LEGACY OF LAVOISIER

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When invited to talk about “the consequences of the Chemical Revolution”, I immediately thought of Sir Christopher Wren’s epitaph in St. Paul’s Cathedral, which he designed and lived to see completed: *Si monumentum requiris, circumspice* (if you would see his monument, look around). The consequences of Lavoisier’s work, it seemed to me, are also around us in the whole structure of modern chemistry. However, on reflection I realized that the analogy is false. Wren’s masterpiece still stands as he left it, having withstood the ravages of nearly three centuries of London weather and the onslaught of the Nazi bombers which ruined its surroundings, but chemistry has changed dramatically since Lavoisier’s time. Some parts of Lavoisier’s chemistry were altered or even abandoned within 20 years of his death; the caloric theory survived until about 1850; but his greatest achievements, the proof of the compositions of air and water and the definition and listing of the chemical elements still survive almost unaltered. This is similar to the fate of many fortunes made by men and women, bequeathed to their immediate descendants and handed down in a family, so I chose the title “The Legacy of Lavoisier” (1).

Before examining the fate of this legacy, I wish to consider briefly the question of the true ownership of the chemical system advanced by Lavoisier in his *Elements of Chemistry* (*Traité Élémentaire de Chimie*, Paris, 1789). In a memoir written in 1792 or early in 1793, Lavoisier stated categorically that the new chemical theory “is mine”, and not, as he had heard it called, “the theory of the French chemists” (2). The words to which he objected so strongly seem to have first appeared in print in J. F. Bonjour’s preface to his translation of T. O.

Bergman’s *Traité des Affinités Chimiques* (Paris, 1788). Bonjour may have used the phrase because the names of four authors - L. B. Guyton de Morveau, A. L. Lavoisier, C. L. Berthollet and A. F. de Fourcroy - appeared on the title-page of the recently published *Méthode de Nomenclature Chimique* (Paris, 1787), in which every substance was given a name that reflected its composition according to the antiphlogistic theory

(3). The new theory was also publicized in Madame Lavoisier’s translation of Richard Kirwan’s *Essay on Phlogiston* (London, 1787), which appeared in Paris in 1788 as *Essai sur le Phlogistique* with an antiphlogistic commentary by Lavoisier or one of his colleagues at the end of each chapter. Like the *Nomenclature Chimique*, the Kirwan translation has several names on the title-page and this may have reinforced the opinion that the theory was that “of the French chemists”. And when *Annales de Chimie*, the journal published by Lavoisier and his colleagues, first appeared in April 1789 its title-page carried the names of no fewer than eight editors.

Lavoisier probably read the words “the theory of the French chemists” in Bonjour’s preface, and he may have seen a similar expression, “the new doctrine of the French chemists”, in the preface to the 4th edition of Fourcroy’s *Éléments d’Histoire Naturelle et de Chimie* (Paris, 1791), but later in the book Fourcroy gave full credit to Lavoisier for discovering the compositions of air and water. Fourcroy did, how-

ever, refer in 1792 to “the theory of the French chemists” in volume 2 of his *Encyclopédie Méthodique, Chimie* (4) and this may have been read by Lavoisier. However, when indignantly asserting that the theory “is mine”, Lavoisier seems to have been over-reacting to an expression used in print only once by Bonjour and rarely by Fourcroy, though of course the offending words may have been spoken in his presence. The first public tribute to Lavoisier was made nearly 18 months after his death, on 22 October 1795, when E. J. B. Bouillon-Lagrange



A curious 19th century woodcut of Lavoisier from the 1874 edition of L. Figuiet's *Vies des Savants Illustres*. Note the erroneous implication that Lavoisier was beheaded with an axe.

described him as having "created a new chemistry" (5), and full credit for the Chemical Revolution was given to Lavoisier by Fourcroy in the long historical account of chemistry that filled most of volume 3 of his *Encyclopédie Méthodique, Chimie*, published in 1797. I think we can assume that the antiphlogistic theory was regarded as Lavoisier's legacy to chemistry, at least by his French contemporaries.

From his own experiments and his reinterpretation of the works of other chemists, Lavoisier was able by 1779 to assert that air is a mixture of oxygen and nitrogen, and by 1784 he was convinced that water is a compound of hydrogen and oxygen. His theory of the composition of water has remained unchallenged, and Lavoisier can hardly be blamed for overlooking Cavendish's observation that a very small proportion of nitrogen seemed to be different from the rest and did not combine with oxygen under the influence of an electric spark, for no one else followed this up until 1894, when Ramsay and Rayleigh detected the presence in the atmosphere of argon, soon to be followed by its companions. Even so, the discovery of the noble gases did not affect Lavoisier's proof that only one constituent of air, oxygen, supported life and combined with combustibles and metals and that phlogiston could be excluded from chemistry.

The other durable part of Lavoisier's chemical legacy was his definition of a chemical element and his list of those substances which possessed the necessary attributes, together with his recognition that the list would have to be modified as chemistry advanced. In his *Sceptical Chymist* (1661), Robert Boyle severely criticized the Aristotelian theory that matter was composed of fire, air, water and earth, but his criticism was destructive and, though he defined elements in language which can be paraphrased as "the simplest products of chemical analysis" he did not name even one substance that satisfied this definition. Several 18th century chemists, including Guyton de Morveau, referred to "chemical elements", which were the simplest substances taking part in chemical reactions, but still believed them to be ultimately composed of Aristotle's four "natural elements" (6). Lavoisier not only proved that air and water are not elements, but showed that there are several distinct earths. However, he retained the elementary fire in his own "caloric", to which I shall return.

Lavoisier's definition of an element was similar to Boyle's, but he drew up a list and, recognizing that it might have to be modified, he preferred to refer to elements as "simple substances not yet decomposed". So this very important part of his legacy to chemistry included the implicit statement that chemistry was a progressing subject and that as new techniques were developed some at least of the "simple substances" might lose that status. This is best shown by his inclusion of the five earths - lime, magnesia, baryta, alumina and silica - even though he demonstrated their resemblances to metallic oxides and surmised that they might indeed be decomposed at some future date. He would not, therefore, have been discontent if he had

TABLEAU DES SUBSTANCES SIMPLES.

	Noms nouveaux.	Noms anciens correspondans.	
Substances simples qui appartiennent aux trois règnes & qu'on peut regarder comme les élémens des corps.	Lumière.....	Lumière. Chaleur. Principe de la chaleur. Fluide igné. Feu.	
	Calorique.....	Matière du feu & de la chaleur. Air déphlogistiqué. Air empiréal. Air vital. Base de l'air vital. Gaz phlogistiqué. Mofete.	
	Oxygène.....	Base de la mofete. Gaz inflammable. Base du gaz inflammable.	
	Azote.....	Soufre..... Phosphore..... Carbone.....	
	Hydrogène.....	Radical muriatique. Radical fluorique. Radical boracique..	
	Substances simples non métalliques oxydables & acidifiables.	Soufre.....	Antimoine.....
		Phosphore.....	Argent.....
		Carbone.....	Arfenic.....
		Radical muriatique.	Bismuth.....
		Radical fluorique.	Cobolt.....
Radical boracique..		Cuivre.....	
Antimoine.....		Etain.....	
Argent.....		Fer.....	
Arfenic.....		Manganèse.....	
Bismuth.....		Mercure.....	
Substances simples métalliques oxydables & acidifiables.	Cobolt.....	Molybdène.....	
	Cuivre.....	Nickel.....	
	Etain.....	Or.....	
	Fer.....	Platine.....	
	Manganèse.....	Plomb.....	
	Mercure.....	Tungstène.....	
	Molybdène.....	Zinc.....	
	Nickel.....	Chaux.....	
	Or.....	Magnésie.....	
	Platine.....	Baryte, terre pesante.	
Substances simples fusibles terreuses.	Plomb.....	Argile, terre de l'alun, base de l'alun.	
	Tungstène.....	Silice.....	
Zinc.....	Terre siliceuse, terre vitifiable.		

Lavoisier's 1789 table of simple substances.

lived to see the proof by Davy and Berzelius in 1808, using the new electrolytic method of decomposition, that lime, baryta and magnesia were indeed metallic oxides.

It may at first seem that Lavoisier was being inconsistent by including in his list the earths, which he suspected to be oxides, but not the alkalis - potash and soda - which he also thought might be compounds. However, his evidence for the compound nature of the alkalis was stronger, though it later proved to be erroneous. Potash was found in the ashes of ordinary vegetable matter and soda in the ashes of plants growing near the sea. Lavoisier believed that they did not exist in living plants but were formed during combustion. Berthollet had shown that the third alkali, ammonia, was a compound of nitrogen and hydrogen, so Lavoisier suspected that nitrogen was a constituent of all three (7). He would probably have been surprised to learn of Davy's discovery in 1807 that potash and soda were in fact metallic oxides.

Lavoisier made it clear that he believed matter to be composed of particles, an opinion that he shared with nearly all 18th century chemists. However, unlike many of his predecessors and contemporaries, he refused to speculate about their nature (8). For many years Robert Siegfried has been arguing, convincingly in my opinion, that the Chemical Revolution was

not complete until after 1803, when John Dalton first showed that Lavoisier's elements could be considered as composed of indivisible atoms, each element having an atom of characteristic weight (9). This important part of Lavoisier's legacy was therefore augmented nearly ten years after his death. The debate about the indivisibility or otherwise of Dalton's atoms started almost immediately, with Davy and William Prout, and continued until the discovery of the electron and other subatomic particles, but for many chemical purposes, Lavoisier's elements and Dalton's atoms are still adequate.

Twenty-three of Lavoisier's original 33 elements still survive in the modern list. Among those that have disappeared are the first two, caloric (heat) and light. An essential part of Lavoisier's system was his theory that heat was a weightless fluid present in all matter. Addition of heat to a solid, liquid or gas normally caused expansion, with a rise in temperature that could be measured with a thermometer, but when a change of state occurred, from solid to liquid or liquid to gas, heat entered into combination with the solid or liquid without a temperature change. Lavoisier thus accounted for thermal expansion and for the latent heats of fusion and evaporation that had been discovered by Joseph Black in Scotland and J. C. Wilcke in Sweden.

Many chemical phenomena could also be explained by the caloric theory. For example, when phosphorus, a solid, burnt in oxygen to form another solid, the oxide, much heat was evolved; this was the caloric originally contained in the oxygen gas. However, less heat was evolved when carbon burnt in oxygen, for the product of combustion was itself a gas which retained some of the caloric from the original oxygen. Some historians have argued that Lavoisier's caloric was, in its chemical manifestations, simply phlogiston transferred from the combustible to the oxygen, but this is not the case, for there was one great difference between the two: caloric could be measured by the use of a suitable calorimeter, but no one ever succeeded in measuring phlogiston liberated during combustion. The weightlessness of caloric was an acceptable concept, for 18th century scientists were familiar with other weightless fluids, notably electricity, but there were a few difficulties. Lavoisier's followers could not explain satisfactorily the exothermic reaction between sulphur and iron filings, for example, since these were both solids which should have contained very little caloric. But there were not many such cases, and chemists generally applied the caloric theory with success until the concept of free energy was developed after about 1850. This was an important part of Lavoisier's legacy.

Although he listed heat and light as separate elements, Lavoisier conceded that they might be modifications of a single element, and his immediate successors found it difficult to reach a decision. Fourcroy, for example, considered them to be distinct in 1795, in his *Philosophie Chimique* (2nd ed.), but by 1800, in his *Système des Connaissances Chimiques*, he presented and obviously favoured the opinion of Gaspard

Monge that heat and light were modifications of the same element, less dense and moving slowly in heat, more dense and moving rapidly in light. However, the problem ceased to interest chemists a few years later when T. Young and A. J. Fresnel found proof of the wave theory of light and it ceased to be considered as a material substance. Even so, "light" appeared in a list of reducing agents on one of the tables displayed in the chemistry laboratory of the British High School that I attended 50 years ago!

Not everyone agreed that heat was a substance. Since the time of Francis Bacon in the early 17th century, some scientists had preferred his theory that heat was simply a manifestation of the motion of particles of ordinary matter, and some experimental support for this was provided by Benjamin Thompson, Count Rumford, in 1798. While in charge of the arsenal at Munich, he used the cannon-making equipment to drill a metal gun-barrel with a deliberately blunted drill-bit and found that he could produce an apparently indefinite amount of heat by friction without in any way altering the chemical or physical properties of the metal. This led him to conclude that heat is motion, not a material substance, but he did not carry out the experiments necessary to establish a quantitative relationship between the heat produced and the mechanical work done in rotating the drill. Had he remained in Munich, he might have continued this research, but he abandoned it when he moved to London and later to Paris, where he married Lavoisier's widow in 1805. The marriage proved to be unhappy and they parted after four years, but the cause of this was not his failure to accept Lavoisier's caloric theory (10).

The theory continued to be useful to physicists as well as chemists, and early in the new century both Dalton and Gay-Lussac used it in their work on the thermal properties of gases. Sadi Carnot was another man who utilized the caloric theory with success. In his study of the efficiency of heat engines, published in 1826, which was of great importance in the development of thermodynamics, he regarded the motive power produced by heat falling from a high to a low temperature as analogous to that produced by water falling from a high to a low level, and treated heat as a fluid in his calculations. His notebooks show that before his early death in 1832 he was leaning towards a kinetic theory of heat, but this work was unpublished and the caloric theory remained generally acceptable until the quantitative research of J. P. Joule and others in the 1840's enabled the mechanical equivalent of heat to be measured and led to a satisfactory kinetic theory of heat and the law of the conservation of energy. This important part of Lavoisier's legacy therefore served science well for half a century (11).

Lavoisier's theory of the nature of acids was less durable. He believed that they owed their acidity to the presence of oxygen, and this was why he chose the name, from *oxus*, the Greek word for acid. He had a sound reason for this belief, for the common inorganic acids (or their anhydrides, as later

chemists called them) were formed when sulphur, carbon, phosphorus and nitrogen combined with oxygen, which was also known to be present in most organic acids, combined with a "radical" composed of carbon and hydrogen. A few metals (arsenic, molybdenum and tungsten) formed oxides with acidic properties and, as Siegfried has recently pointed out, Lavoisier believed that all metals would yield acids if combined with sufficient oxygen and in his table of elements he described metals as "oxidable and acidifiable" (12).

Even as early as 1789 the oxygen theory of acids had run into some difficulties. No oxygen had been found in muriatic (HCl), boracic (H_3BO_3) or fluoric (HF) acids, so Lavoisier assumed that they were compounds of oxygen with radicals that were yet to be discovered and included these radicals in his list of elements. In view of the large number of acids that do contain oxygen, I think he was justified in doing this, in the same way that Mendeleev was later justified in leaving blank spaces in his periodic table for undiscovered elements. However, Lavoisier's treatment of prussic acid (HCN) was unsatisfactory, for Berthollet had shown in 1787 that it consisted only of carbon, nitrogen and hydrogen. In his *Traité* Lavoisier failed to mention the hydrogen, stating only that Berthollet had found carbon and nitrogen, and, while admitting that the substance combined with alkalis, earths and metals like other acids, he added, with no details, that it possessed only some properties of acids and should not perhaps be included in that class (13). Clearly he was worried about this apparent anomaly in his acid theory, but it was not regarded as a serious problem by Fourcroy, who later pointed out that Berthollet had not performed a complete analysis and thus there was still a possibility that oxygen might be found (14).

Thomas Thomson, on the other hand, considered that Berthollet's analysis rendered the presence of oxygen "somewhat unlikely" and also pointed out that sulphuretted hydrogen (H_2S) possessed all the properties of an acid but contained no oxygen, and concluded by writing: "all that can be meant, then, when it is said that oxygen is the acidifying principle, is merely that it exists as a component part in the greater number of acids, and that many acids are formed by combustion, or by some equivalent process" (15). This was written in 1804, only ten years after Lavoisier's death. Already, an important part of his legacy was no longer intact.

When muriatic acid reacted with manganese dioxide it yielded a gas which dissolved in water to form an acid solution and, on exposure to light, the solution gave off oxygen. This was therefore known as oxymuriatic acid and was considered to be composed of the unknown muriatic radical combined with more oxygen than ordinary muriatic acid (16). However, although the solution of oxymuriatic acid apparently contained oxygen, the gas showed no signs of its presence. In 1808 two of the younger French chemists, J. L. Gay-Lussac and L. J. Thenard, tried without success to decompose oxymuriatic acid gas with heated carbon but, while admitting that this might

show that the gas was in fact an element, they preferred to continue to believe that it contained oxygen. They were probably affected by loyalty to the French founder of the oxygen theory of acids, but Humphry Davy had no such feelings and in an extensive series of experiments in 1810 he failed to remove oxygen by using several reagents and became convinced that oxymuriatic acid gas was an element, which he named chlorine, and, further, that muriatic acid itself was a compound of chlorine and hydrogen. Gay-Lussac accepted this theory in 1814 and, as Partington puts it, "Lavoisier's oxygen theory of acids had now gone the way of phlogiston" (17). Curiously, no one has ever suggested that the name "oxygen" should be changed, so that important part of Lavoisier's legacy is still with us even though, contrary to the laws of nomenclature which he helped to formulate in 1787, the name of one of the most common and important elements now bears no relation to its properties.

Lavoisier's original name for the gas was "eminently respirable air" which he changed to "vital air" on the recommendation of Condorcet, the Secretary of the Academy of Sciences. This name referred to its ability to support life, and Lavoisier connected this to his theory of combustion, believing that, as a result of respiration, oxygen was absorbed in the blood where it reacted with carbon and hydrogen, derived from the digestion of food, and liberated the caloric which kept the body at a higher temperature than its surroundings. It was many years before physiologists elucidated the exact mechanism of this process, but Lavoisier was correct in principle and his theory of animal heat was an important part of his legacy.

Fourcroy had qualified as a physician and was always interested in the applications of chemistry to medicine. In 1789



Claude Louis Berthollet



Antoine Francois Fourcroy

he studied the effect of administering oxygen to sufferers from tuberculosis and found that they became feverish, an effect which, applying Lavoisier's theory, he attributed to the increased liberation of caloric in the body. On the other hand, languorous patients, or those with a lower temperature than normal, benefited from breathing more oxygen. It was commonly thought that the composition of the atmosphere varied from place to place, and during his travels in the Alps, H. B. de Saussure had carried out eudiometric experiments at various altitudes, but, probably because he used a faulty method, he concluded that air was best for respiration between about 800 and 1200 feet above sea level (18). Fourcroy may have been aware of Saussure's work, for he recommended that feverish patients should be kept at ground level but those suffering from languor would benefit by being sent to a high altitude (19). This was a rational suggestion until eudiometric methods were improved and, more importantly, until Gay-Lussac in 1804 made two balloon ascents, accompanied on one of them by J. B. Biot and, among other scientific experiments, took a sample of air at 6,000 metres which was found to have the same composition as that in Paris.

Gay-Lussac and Biot were members of the Société d'Arcueil, founded by Berthollet and Laplace, the great mathematician, in 1807, though the informal meetings that led to its formation began several years earlier. They owned neighboring houses in the village of Arcueil, near Paris, and it was there that about 15 members met regularly to perform experiments and discuss their scientific ideas in a less formal atmosphere than that of the Institut, to which most of them had been elected. Berthollet and Laplace were among the earliest converts to Lavoisier's new chemistry who had met regularly in his laboratory, and Maurice Crosland has argued persuasively that at Arcueil they

were continuing Lavoisier's research program. He has called the Arcueil group "the heirs of Lavoisier" and, while I do not disagree with him, I should like to point out that they were not Lavoisier's only heirs (20). Part of Lavoisier's legacy was his pioneering work on organic analysis, and this was continued by Fourcroy and his former student, L. N. Vauquelin (1763-1829), who worked at the Muséum d'Histoire Naturelle and were not associated with the Arcueil group.

When Lavoisier and his colleagues were replying in 1788 to Kirwan's *Essay on Phlogiston*, it was Fourcroy who was chosen to comment on the chapter on the acid of sugar (oxalic acid), for he had specialized most on the chemistry of vegetable and animal substances. Lavoisier had earlier shown that organic matter consisted mainly of carbon, hydrogen, oxygen and nitrogen, and he attempted to determine their proportions in a variety of substances, such as sugar, alcohol, olive oil and various gums. He used several methods. Fermentation (in the case of sugar) yielded carbonic acid (carbon dioxide), which could be collected and measured and thus provided a measure of the carbon content of the sugar. In other cases he obtained the carbon dioxide from his sample by combustion in oxygen or heating with certain metallic oxides, particularly mercuric oxide, which readily lost its oxygen. Much of this work was done in 1787 and 1788, but remained unpublished, and his laboratory notes show that he obtained very inconsistent results because of his doubts about the purity of the mercuric oxide and his uncertainty about the percentage of carbon in carbonic acid (21).

Another reason for Lavoisier's difficulties with organic analysis may have been that he was working with impure



Louis Nicolas Vauquelin

natural substances of varying composition. He was skilled in most branches of practical chemistry, but had little experience of the techniques required for extracting pure compounds from crude vegetable and animal matter. This was a field in which Fourcroy excelled, even before 1790 when he began to enjoy the collaboration of Vauquelin. They developed a procedure for extracting pure compounds by systematic extraction with water, alcohol, ether and dilute acids and alkalis and worked on many vegetable and animal substances until Fourcroy's death in 1809 (22).

Before joining Fourcroy at the Muséum d'Histoire Naturelle, Vauquelin had taught at the Collège de France and the École Polytechnique (where he was also Fourcroy's colleague) and in a private laboratory which he owned jointly with Fourcroy and in which they manufactured fine chemicals. Vauquelin employed several young men as assistants and trained them well in practical chemistry. Two later achieved great distinction, namely L. J. Thenard (1777 - 1857) and M. E. Chevreul (1786 - 1889), who began to work with Vauquelin about 1797 and 1803 respectively. They both became skilled at the isolation of pure organic compounds from natural substances.

After his early experience with Vauquelin, Thenard was accepted into the Arcueil group and, with Gay-Lussac, he devised a method for the elementary analysis of organic compounds by combustion with potassium chlorate. Gay-Lussac later improved it by using cupric oxide as the oxidizing agent. Thenard and Gay-Lussac both did research on other branches of chemistry, but Chevreul, who remained with Vauquelin at the Muséum after Fourcroy's death and did not belong to the Arcueil group, devoted himself to organic chemistry. From about 1811 to 1820 he carried out many fundamental experiments on animal fats, proving that they were compounds of glycerol with various organic acids, which he isolated and purified using the techniques learned from Vauquelin, and he characterized them by their melting points, a method introduced by Fourcroy as early as 1786, but rarely used since then. He also showed that, during the saponification of a fat with alkali, it was broken into its components, the glycerol being liberated and the alkali combining with the acid to form a soap. At every stage he determined the carbon, hydrogen and oxygen in his products, using a modification of Gay-Lussac's copper oxide method, and his quantitative analyses supported his qualitative conclusions (23).

Before his death, Lavoisier claimed that he had the first ideas concerning the composition of plant and animal substances (24). I think that Fourcroy, Vauquelin and Chevreul deserve much credit for preserving this part of his legacy.

Lavoisier did not use potassium chlorate, which had been discovered by Berthollet, for organic analysis, but his laboratory notebooks show that on 22 and 24 October 1788 he examined its reaction with carbon. This research was done in connection with his work for the Régie des Poudres, the royal gunpowder manufacturing monopoly of which he was one of



Michel Eugène Chevreul

the directors. A few days later, on 27 October 1788, Lavoisier and his wife, with Berthollet and some other officials and visitors, were present at the gunpowder factory at Essonnes, about 40 kilometres south of Paris, when an attempt was made to manufacture a batch of powder with potassium chlorate instead of the usual nitrate. An explosion killed two people, and the use of chlorate was abandoned for military gunpowder, though it was later used in pyrotechnics (25).

His scientific and administrative skills made Lavoisier a valuable member of the Régie des Poudres, but he was not involved in the day-to-day operation of the factory at Essonnes. However, in 1787 he was able to secure an appointment there for Eleuthère Irénée du Pont (1771-1834), the younger son of his friend Pierre Samuel du Pont (1739-1817), the economist. The young man worked there until 1791, and learned enough to set up his own gunpowder mill at Wilmington, Delaware, after the du Pont family emigrated to America in 1799. He originally called it the Eleutherian Mills, incorporating his own first name, but on 12 June 1803 he wrote to his father that he had "definitely decided on Lavoisier Mill which is suitable and which shows my gratitude to one whose goodness to me was the first cause of my enterprise". His brother Victor, writing from New York on 13 July 1803, addressed his letter to "E. I. du Pont de Nemours, Esquire, Lavoisier's Mills, near Wilmington, Delaware", but, for an unknown reason the name was not retained, and on 2 May 1804 Victor suggested "E. I. du Pont de Nemours Gun Powder Manufactory" (26).

E. I. du Pont de Nemours had no idea that his powder mill would grow into one of the world's greatest industrial companies. It is, perhaps, a pity that he did not keep his patron's name in its title, but even so it remains as part of Lavoisier's legacy to chemistry and industry.

References and Notes

1. A similar expression, "the legacy of his achievement" is included in a valuable appraisal of Lavoisier's place in chemistry by A. Donovan, "Lavoisier and the Origins of Modern Chemistry", *Osiris*, **1988**, *4*, 214-231.
2. A. L. Lavoisier, *Mémoires de Chimie*, Vol. 2, Paris, 1805, p. 87. This work was published in 1805 by Lavoisier's widow. See W. A. Smeaton, "Madame Lavoisier, P. S. and E. I. du Pont de Nemours and the Publication of Lavoisier's 'Mémoires de chimie'", *Ambix*, **1989**, *36*, 22-30.
3. See B. B. Chastain, "Books of the Chemical Revolution. Part 1. Méthode de Nomenclature Chimique", *Bull. Hist. Chem.*, **1989**, *3*, 7-11. Chastain (p. 8) points out that the authors were listed in decreasing order of age, Guyton being the oldest.
4. A. F. Fourcroy, *Encyclopédie Méthodique, Chimie*, Vol. 2, Panckoucke, Paris, 1792, p. 54.
5. E. J. B. Bouillon-Lagrange, "Rapport sur les Progrès de la Chimie, et sur ce qu'elle doit aux Travaux de Lavoisier", in L. Scheler, *Lavoisier et la Révolution Française. I. Le Lycée des Arts*, revised ed., Hermann, Paris, 1957, pp. 66-76. The report originally appeared in 1796 in the very scarce *Journal du Lycée des Arts*.
6. M. Boas, "Structure of Matter and Chemical Theory in the 17th and 18th Centuries", in M. Clagett, Ed., *Critical Problems in the History of Science*, University of Wisconsin, Madison, 1959, pp. 494-512.
7. A. L. Lavoisier, *Elements of Chemistry*, trans. R. Kerr, Creech, Edinburgh, 1790 (facsimile reprint, Dover, New York, 1965), pp. 155-156.
8. *Ibid.*, p. xxiv.
9. R. Siegfried and B. J. T. Dobbs, "Composition: A Neglected Aspect of the Chemical Revolution", *Ann. Sci.*, **1968**, *24*, 275-293; R. Siegfried, "The Chemical Revolution in the History of Chemistry", *Osiris*, **1988**, *4*, 34-50.
10. D. I. Duveen, "Madame Lavoisier", *Chymia*, **1953**, *4*, 13-29.
11. For a full discussion of the caloric theory see R. Fox, *The Caloric Theory of Gases From Lavoisier to Regnault*, Clarendon Press, Oxford, 1971.
12. R. Siegfried, "Lavoisier and the Phlogistic Connection", *Ambix*, **1989**, *36*, 31-40 (especially p. 34). It was thought that the word "acidifiable" applied to metals was a mistake and that it should have read "salifiable", by J. R. Partington, *A History of Chemistry*, Vol. 3, Macmillan, London, 1962, p. 485. However, there is no doubt that this is one of the rare occasions when Partington was wrong.
13. Reference 7, pp. 289-290.
14. A. F. Fourcroy *Système des Connaissances Chimiques*, Baudouin, Vol. 9, Paris, 1800, p. 92.
15. T. Thomson, *A System of Chemistry*, 2nd ed. Bell and Bradfute, Edinburgh, 1804, pp. 3-4 (acids in general) and p. 183 (prussic acid).
16. In modern terms, muriatic acid is HCl and oxymuriatic acid gas is Cl₂. In solution, Cl₂ + H₂O → HCl + HOCl and on exposure to light 2HOCl → 2HCl + O₂.
17. A good account of the work on chlorine is given by J. R. Partington, reference 12, Vol. 4, pp. 51-55 (my quotation from p. 55).
18. W. A. Smeaton, "The Chemical Work of H. B. de Saussure, With the Text of a Letter Written to him by Madame Lavoisier", *Ann. Sci.*, **1978**, *13*, 1-16.
19. W. A. Smeaton, *Fourcroy, Chemist and Revolutionary*, Smeaton, London, 1962, pp. 136-138.
20. See three works by M. P. Crosland: *Les Héritiers de Lavoisier*, Paris, 1963 (a lecture delivered at the Palais de la Découverte); *The Society of Arcueil*, MIT, Cambridge, MA., 1967; and *Gay-Lussac, Scientist and Bourgeois*, Cambridge University Press, Cambridge, 1978.
21. A full account of Lavoisier's work on organic chemistry, with many references to his unpublished manuscripts, is given by F. L. Holmes, *Lavoisier and the Chemistry of Life*, University of Wisconsin, Madison, 1985.
22. Reference 19, pp. 136-176.
23. W. A. Smeaton, "Michel Eugène Chevreul", *Endeavour*, **1989**, *13*, 89-92.
24. Reference 2, *Mémoires*, p. 87.
25. The explosion was mentioned in a letter from Madame Lavoisier to Saussure, 2 January 1789, and is discussed in reference 18, pp. 11-13.
26. The du Pont correspondence is published by B. G. du Pont, Ed., *Life of Eleuthère Irénée du Pont from Contemporary Correspondence*, 11 Vols. + Index, Newark, Delaware, 1923-27. For a discussion of relevant extracts, see W. A. Smeaton, reference 2. In 1789 P. S. du Pont was elected to the Estates-General as a deputy of the Third Estate for the town of Nemours, about 90 kilometres south of Paris. After the French Revolution the family adopted the name du Pont de Nemours.

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LAVOISIER'S POLITICS

Arthur L. Donovan, U.S. Merchant Marine Academy

Antoine Lavoisier, one of history's greatest scientists, was also a prominent public administrator during the final decades of the Old Regime. Several of his involvements in public affairs are fairly well known. For years he served on commissions and committees of the Academy of Sciences, as a Director of the National Gunpowder Administration, and as a tax farmer