

Louis-Bernard Guyton de Morveau

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Resumen

Louis-Bernard Guyton de Morveau (1737-1816) es considerado uno de los más importantes miembros del grupo de científicos franceses que en siglo dieciocho destronaron la teoría del flogisto y establecieron el marco de la química moderna. Su contribución al estudio de la afinidad química, al establecimiento de normas racionales de nomenclatura química, y al desarrollo de la educación superior fue decisiva en una época crítica de la ciencia en Francia. Durante la mayor parte de su vida Guyton fue un firme partidario de la teoría del flogisto, pero eventualmente aceptó los descubrimientos de Lavoisier y ayudó a establecerlos como hechos irrefutables.

Life and career

Louis-Bernard Guyton de Morveau (1737-1816) (Figure 1) was born on January 4, 1737, at Dijon, France, the eldest son of Marguerite Desaulle and Antoine Guyton, a lawyer and professor of French law at the *Université de Dijon*. His father was descendent from an ancient and respectable family originating from Beaune and Autun that included many surgeons, lawyers, and military officers. Louis-Bernard's younger brother, Philibert, was born in 1738 and, as was the custom, took the habits and devoted himself to counselling and writing (Bouchard, 1938; Granville, 1817; Smeaton, 1957)

Louis-Bernard received his basic education at home, with private teachers engaged by his father and afterwards, at the age of ten, entered the *Collège Godran*, a secondary school at Dijon managed by the Jesuits and providing a classical education, with little teaching of sciences. He finished school in 1753 at the age of sixteen and then entered the Faculty of Law of Dijon to study law, from where he graduated in 1756. In the same year he was admitted to the bar and then practiced law for six years.

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Dijon was the ancient capital of Burgundy and the seat of the French provincial parliaments or royal courts of law. The venality of the administration had incited the royal power, lacking enough income, to multiply without limit the number of offices and officers. A seat in a parliament, which carried with it social prestige and exemption from certain taxes, could be bought and sold. In 1762, Nicolas Generau, one of the two *avocat-général du Roi* in the Dijon parliament, had to resign to his office in order to pay his creditors. Guyton's father took advantage of this opportunity to purchase this position for his son Louis Bernard for the sum of forty thousand francs (according to Bouchard the sum was thirty-four thousand). Bouchard (1938) mentions two interesting facts, one that Guyton's appointment required the especial permission by the King because at that time he was only twenty-five years old, which was below the legal requirement of thirty years, and the second, that the annual income report did not exceed 1500 livres of which 1300 went for paying the servants and the rest represented the value of the candles and salt paid in kind.

After his appointment Guyton added to his name *de Morveau*, from a family property near the city and retained this name, signing himself simply De Morveau until the French revolution, when, like many Frenchmen, he dropped the *de* and became Guyton-Morveau, then Guyton, and finally Guyton-Morveau again (Smeaton, 1957).

Guyton served as *avocat-général* for twenty years until March 26, 1783, when he retired and was given the title of *avocat-général honoraire*, together with a pension and certain hereditary privileges. After retirement he published his most important legal speeches in a book entitled *Discours Publics et Éloges* (Guyton de Moveau, 1775) that also included a letter to a fictitious correspondent, in which he delineated his plan for reforming the French legal system. Guyton proposed nominating a committee of judges to interpret the different regulations and to establish in France "une jurisprudence simple, uniforme, universelle et constante" (a simple, uniform, universal and constant jurisprudence).

According to Bouchard (1938) Guyton was not

in good relations with his colleagues. In one opportunity he spoke about “ces magistrates qui croient que les tribunaux sont de superbes boutiques où ils revendant en détail l’autorité qu’il sont achetée” (these judges that believe that the courts are superb boutiques where they retail the authority they have purchased). Another important quote is from a speech he made in 1777 criticizing the chaotic state of French legislation: “Que pensera la postérité, lorsqu’elle verra un seul code, un seul législateur et deux cent quatre-vingt-cinq codes différents?” (What will posterity say when they will see one people, one legislator and 285 different legal codes?).

Guyton parliamentary duties kept him very busy, but he found time for other activities and on January 20, 1764 he was elected an *honoraire* member of the *Académie des Sciences, Arts et Belles-Lettres de Dijon*. At first he read only literary contributions at its meetings but he became so interested in science that in 1768 he acquired a house in the Place St. Jean in Dijon, fitted it with a laboratory, and thenceforth devoted to chemistry all the time he could spare from his parliamentary duties. He became such a strong believer in the power of chemistry that he declared that in the eighteenth century anyone who considered himself well informed should blush if he had no knowledge of this science (Bouchard, 1938).

He carried out research in a wide variety of topics, and many of his papers appeared in the *Mémoires* of the Dijon Academy and in the monthly journal *Observations sur la Physique*. In 1772 he published his first scientific book, *Disgressions Académiques* (Guyton de Morveau, 1772), containing the two long and important essays on chemical affinity and on phlogiston, *Dissertation sur le Phlogistique Considérée Comme Corps Grave* and *Essai Physico-Chymique Sur la Dissolution et la Crystallization, Pour Parvenir à la Explication des Affinités Par la Figure des Parties Constituants des Corps*, and a third short one, *Observation sur une Nouvelle Espèce de Guhr* (a colloidal form of silica).

Guyton many activities led to his appointment as *correspondent* (corresponding) member of the *Académie Royale des Sciences* in March 1772, shortly before the publication of his first book *Disgressions*. In the same year he became vice-chancellor of the Dijon Academy and in 1781 he was elected to be its chancellor. During his administration the Académie de Dijon, was changed from an intellectual to a teaching establishment. In his own words, the purpose of the Académie should be “de vulgarizer la science pour lui recruter des adeptes, en répandre le

gout et guider les arts mécaniques” (to popularize science in order gain adepts to spread the taste and guide the mechanical arts).

Guyton was now recognized as a leading authority on chemistry and in 1780 he was commissioned to write the four *Suppléments* (supplementary) volumes of the chemical

volumes of the new *Encyclopédie Méthodique*. This major work was intended to replace the great *Encyclopédie* of Denis Diderot (1713-1784) and Jean Le Rond D’Alembert (1717-1783) in which articles on all subjects were arranged in one alphabetical sequence; in the new *Encyclopédie* each subject was now treated separately. The supplements contain about twelve entries carrying Guyton’s name on such varied subjects as acids, affinity, air, combustion, calcinations, crystallization, dissolution, hepar, the lightning conductor, phlogiston, and steel. The most important entry is the one about acids (*Acide*); it contains 415 pages (more than fifty percent of the pages of volume I) and encompasses a study of all the acids known at that time. It is a good testimony of the many wrong ideas prevalent at that time; for example, the formation of acids was due to “le feu l’air fixe” (acids originated by the action of the fixed air fire, carbon dioxide). In his entry *Hépar* Guyton condemned the use of the word *foie* (liver) in such names as *foie de soufre* and *foie d’arsenic*. These names, he said, were absolutely improper being based solely on the purely accidental red colour of the substances. He replaced the word *foie* by the Latin equivalent *hépar*, as word with no common association. The class *hépars*, thus freed from any common association, was enlarged by Guyton to include all salts with three components; the sulfides were among these, being thought of a base combined with sulfuric acid and phlogiston (Smeaton, 1954).

Guyton de Morveau’s reputation is based more on his dedication to the teaching of chemistry and its application to industry, that on his experimental work, that nevertheless were numerous. The most



Figure 1. Louis-Bernard Guyton de Morveau (1737-1816).

important of the latter are the use of zinc white in paint, discovery of the disinfecting action of chlorine, the principles of volumetric analysis, and particularly, the first coherent essay ever about chemical nomenclature and classification.

He practiced chemistry for eleven years and then published his classes under the title *Elémens de Chimie Théorique et Pratique* (Guyton de Morveau, 1777). The publication of this book is a benchmark in the history of physical sciences; the book was used by all French laboratories and was translated into many languages. In the introduction to the book Guyton wrote that all the theory of chemistry was in the two words *attraction*, *equiponderance* (the equality of weight or attraction to the centre of the earth) and all the practice of the two in the two other words, *dissolution*, *crystallization*.

Guyton gathered around him many collaborators, particularly medical doctors that provided him with the necessary knowledge about chemistry and who taught courses on mineralogy, botany, medical subjects, anatomy, and obstetrics. He also translated and published many scientific books that had been originally published in Swedish, English, and German. He published under his name a two-volume translation of Torbern Olof Bergman's (1735-1784) *Opuscules Chimiques et Physiques*, containing about one thousand pages, of which about two hundred correspond to Guyton's remarks. In 1785 he also published a translation of Carl Wilhelm Scheele's (1742-1786) works, under the title *Mémoires de Scheele*. This two-volume book contains twenty-seven memoirs describing Scheele's principal discoveries, mainly oxygen, chlorine, glycerol, barite, copper arsenate (Scheele's green), hydrogen fluoride, manganic acid, molybdic acid, benzoic acid, lactic acid, citric acid, and hydrogen cyanide. M^{me} Claudine Picardet (maiden name Poulet, the wife of a member of the Dijon Academy) that served as Guyton's laboratory assistant and secretary, made most of these translations; Claudine was very rich and beautiful and it was rumoured that she was Guyton's mistress. Eventually Guyton married her when he was sixty-one years old and M^{me} Picardet had become widow and poor.

At the Thermidor Convention and the Council of the Five-Hundred, Guyton was made responsible of organizing the *Grand Écoles* (institutions for higher learning) and, in particular, the *École Centrale des Travaux Publics*, (1794) which in 1795 became the *École Polytechnique*. He was appointed to one of the three chairs created for the latter, as well as

directed it during three years. He retired from the École Polytechnique about 1811 but retained the important post of Administrator of the Mints (until 1814) to which he had been appointed by Napoleon in 1799, as well as continued to be an active editor of *Annales de Chimie*, of which he had been one of the founders in 1789 (Bouchard, 1938; Granville, 1817).

In 1777 Guyton de Morveau and Champy, the commissar for gunpowder and saltpetre of Bourgogne, established a society to build a *nitrière artificielle* for manufacturing potassium nitrate. The facilities opened on 1780 under the supervision of Jean-Baptiste Courtois (the father of Bernard Courtois, the discoverer of iodine) who was then working as his *préparateur* at the Académie de Dijon. Eventually, Jean-Baptiste bought the *nitrière* and abandoned his job at the Académie (Wisniak, 2002).

In 1783 Guyton established the first French soda factory using a process due to Scheele in which a paste made of slaked lime and saturated brine was allowed to effloresce on exposure to the atmosphere. The layer of crude carbonate thus formed was removed and the efflorescence process repeated until exhaustion. Calcination of the remaining insoluble solid yielded lime that was used again in the process. The sodium carbonate produced was purified by successive crystallization.

Under the Empire, Guyton was decorated and awarded a baronetcy. At the beginning of the Second Restauration, he was expelled from the École Polytechnique because at the time of the Convention he had voted in favour of the death penalty for Louis XVI. In addition he was deprived of his pension and exiled. All these misfortunes led to his death in Paris, on January 2, 1916, at the age of sixty-nine years.

The life work of Guyton de Morveau has been well-defined by what Michel Chevreul (1786-1889) wrote in his study about the scientific contribution of Antoine Laurent de Lavoisier (1743-1794) and his contemporaries: "C'est plutôt comme promoteur de la science que comme auteur de recherches chimiques exécutés dans le laboratoire, que le nom de Guyton de Morveau est inscrit d'une manière distinguée dans les archives de la science. Il appartient au groupe des savants que nous nommons littérateurs chimistes" (The name of Guyton de Morveau is inscribed in a distinguished manner in the archives of science more as a promoter of science than as the author of chemical research performed in the laboratory. He belongs to the group of scholars that we call chemical literates).

Main contributions

Guyton published many memoirs and papers in scientific journals, particular in the *Journal de Physique*. Regarding industry, he studied the metallurgy of iron at Creusot, with the first franchise owner, and also at Montard with George-Louis Leclerc Buffon (1707-1788). He exploited a coalmine, established a glass factory, a zinc white factory, etc. etc.

Guyton's first scientific publication was entitled "Mémoire Sur les Phénomènes de l'Air Dans la Combustion" (Guyton de Morveau, 1769) in which he described the experiments that led him to believe that while air was necessary for the combustion to take place, its action was pure mechanical and was not partly consumed as had been suggested by Stephen Hales (1677-1761). Hales had written that "fire consumes air as its food"; Guyton on his part believed that the real food of fire were the materials being burnt and not the oxygen present in the air. At the time of Guyton's work, Antoine-Laurent Lavoisier (1743-1794) had yet to make known his ideas regarding the relation between burning matter and fire, the sensible manifestation of the combustion phenomenon. It was then believed that fire pre-existed in nature in certain bodies and was released when they burned. Guyton was intent in proving that air did not take part materially in the combustion process, that the phenomenon took place only for a given air pressure and that action of the gas was purely mechanical. If a candle extinguished after burning in a closed place it was not because it lacked "food" but because of the excess in pressure caused by the dilation of air. In 1787 he became an enthusiast follower of Lavoisier and collaborated with him in many enterprises. In addition to Lavoisier, for more than forty years he conducted a very active correspondence with the important European chemists (Bouchard, 1938; Carlid and Nordström, 1965; Smeaton, 1967).

Guyton's most important publication in his final years was the *Traité des Moyens de Désinfecter l'Air* (Guyton de Morveau, 1802, 1805), in which he gave a full account of his work on disinfection by the vapors of muriatic acid and oxymuriatic acid (chlorine). This work was the result of an incident that took place in February 1773 at Dijon. At that time it was customary to bury the dead in churches. The 1773 winter was very hard, the ground had frozen and it was impossible to dig tombs. As a result unburied bodies accumulated in the caves of Dijon's cathedral (the church of St. Médard) and their decomposition

resulted in such an unbearable odour that it became impossible to enter the church; a state of epidemics was declared in the quarter. The authorities sought Guyton's advice after none of the usual remedies (adding lime, burning potassium nitrate, and fumigations of vinegar) helped. Guyton knew that volatile alkali (ammonia) was sometimes evolved from decaying animal matter and thought that it carried with it particles of unhealthy emanation. He also knew that marine acid (hydrogen chloride) fumes caused the volatile alkali to precipitate and thus reasoned that the emanation would fall to the ground as soon as its supporting alkali was removed. He made a "poetical" comparison between the odour abatement and the flying of a bird: "Je fis réflexion que l'odeur putride ne pouvait être composée que de l'alcali volatile qui se dégage en abondance lors de la putréfaction et de l'huile animale âcre dont il était souillé et qui affectait particulièrement l'organe de l'odorat. Cette huile étant par elle-même assez pesante, je considérai l'alcali comme un oiseau dont les ailes trempées dans la liqueur ichoreuse, élevait jusqu'à nous cette matière fixe, et qu'il n'était question d'arrêter son vol pour rendre l'huile fétide à son inertie" (I have remarked that the putrid smell must be composed of volatile alkali that is released plentifully during putrefaction and from the acrid animal oil that it has polluted and that it affects particularly the smelling organ. This oil is heavy by itself, thus I consider the alkali to be like a bird that after having its wings soaked in the acrid liquor carries toward us this fixed matter, and that does not stop its flight to provide inertia to the fetid oil) (Bouchard, 1938).

Based on this reasoning he heated a mixture of common salt and vitriol in a furnace warmed by a sand bath and left it overnight in the church. After forty-eight hours the odour had gone and the district was once again healthy. In December of the same year he successfully repeated the process in the Dijon prison, where many prisoners had died. Later on Guyton improved his process by replacing hydrogen chloride with chlorine. The procedure became known as *fumigations guytoniennes* (Guytonian fumigations). This work on public health led in 1805 to Guyton being appointed an officer of the *Legion de Honneur* for his service to humanity.

By the time of the French revolution he had become the most famous citizen of Bourgogne. His liberal ideas led to his election as *procureur général* (general prosecutor, with responsibility for ensuring that all new laws were enforced) of the Côte-d'Or

Department and, later on, deputy to the Legislative Assembly. He was sent to the Convention and served in the first Committee for Public Health. In the latter position he named several famous scientists as advisors, among them, Claude-Louis Berthollet (1748-1822), Jean-Antoine Chaptal (1756-1832), Antoine-François Fourcroy (1750-1809), and Gaspar Monge (1746-1818). His most important role came after July 10, 1793, when together with Lazare Carnot (1753-1823) and Prieur de la Côte-d'Or (1763-1832), which were members of the second Committee for Public Health, he organized the harvest of saltpetre and the manufacture of gunpowder and weapons.

At the Meudon weapon's testing facilities, he improved the shooting grounds and invented a new type of cannonball. Before his invention iron or bronze cannonballs were made slightly smaller than the gun-barrel to prevent binding, with the resulting loss of gas. Guyton's new cannonball was cylindrical with a hemispherical head; a projecting ring of lead at the base of the hemisphere enabled it to fit tightly in the gun barrel eliminating loss of gas and increasing the range ("de faire fonder des boulets cylindro-sphériques, avec une rainure circulaire au-dessous de la demi-sphère, destinée à recevoir une bague de plomb") (Bouchard, 1938).

Guyton was one the first Frenchmen to become interested in the discoveries of the brothers Joseph and Étienne Montgolfier and the first one to use them for military purposes. None of the high-ranking officers in the French Army had considered such possibility, not even general Jean-Baptiste Marie Meusnier (1754-1793), a well-known physicist and long-time collaborator of Lavoisier (Bouchard, 1938). In 1784 Guyton carried out two free balloon ascensions at Dijon and eventually became one the experts in this technique. On June 2, 1793, the Committee of Public Health requested from him to examine and report on the possible use of the aerostat used by Lallement Sainte-Croix to fly over the Champs-Élysées. Guyton concluded that the globe could carry three persons and would be very appropriate for aerial observation if it were anchored with cables. For elevation purposes he decided on the use of "gas inflammable" (hydrogen), prepared by reacting water over hot iron. The balloon, named *l'Éprouveur*, was transported to the secret military establishment at Meudon where it was tested again and again while Guyton developed the set of instructions to be used for communication with the ground forces during day and night time. In spite of the strong hostility of

many generals against this project he succeeded in imposing it on the armed forces and he was present on June 26, 1794 when observers in a captive balloon threw out reports on the Austrian positions during the French victory at Fleurus, in Belgium, which paved the way to Brussels.

Phlogiston

In the beginning of his career Guyton was a staunch supporter of the phlogiston theory and in 1772 he exposed his ideas and conclusions in his memoir *Dissertation sur le Phlogistique Considérée Comme Corps Grave*, the first of three essays published in his *Disgressions Académiques* (Guyton de Morveau, 1772). This memoir may be considered the most comprehensive exposition of the phlogiston theory available at that time. Guyton first established that when a metal was calcined its weight increased; the decrease in weight reported by earlier workers was due only to mechanical loss or volatilization. He then proceeded to expose his theory that the presence or absence of phlogiston was the only cause of the change in weight. Phlogiston was specifically lighter than air, actually lighter than any substance. Therefore, its combination with any other substance necessarily resulted in an apparent diminution in the weight of the substance; independent of the medium in which the weighing was performed. Phlogiston, or the inflammable principle, was a substance that could not be explained with common arguments; it had never been obtained free from other matter, and its existence and its properties could be deduced only by the fundamental role it played in nature. Common belief had it that phlogiston was material and hence it had weight (*elle est matière donc elle est grave*) as shown by the gain in weight of metals on calcinations. According to Guyton the presence or absence of phlogiston was the real cause of the decrease or increase of the gravity of the bodies that could combine with it. He claimed that phlogiston could not gravitate in air because it was essentially volatile. On being set free by a body it rose immediately in the air and communicated its volatility to the bodies with which it combined. The immediate cause of volatility was the excess of the gravity of the medium over that of the volatile body. This volatility ceased to be manifested as soon as the quantity of the fixed substance was sufficient to produce a combined density (*densité composée*) exceeding that of the surrounding fluid. All volatile substances owed their volatility to the presence of some phlogiston and lost their volatility when

it was removed. The lesser gravity of phlogiston in air was proved by the direction it took when it was free and by the speed with which it moved in that direction (Partington and Kie, 1937; Smeaton 1964).

Guyton's ideas were seriously attacked and criticized; it was argued that if phlogiston were so volatile then it would be unrestrainable as fire and as capable as steam of overcoming great resistances. It would constantly strive upwards and all bodies that contained it would insensibly lose it. Putting in modern terms what an antagonist wrote regarding Guyton's ideas: phlogiston was identical to an *unknown virus* or to *aspirin*. It was very a very convenient and versatile idea used by chemists whenever they needed it because of its possibility of explaining the most contradictory facts.

According to Duveen and Klickstein (1956), by 1778 Lavoisier had developed his theory that combustion and calcinations depended on the combination of the combustible or metal with oxygen; he used all the experimental information he had accumulated to attack the concept of phlogiston. Lavoisier's findings led not only to a turn around of Guyton's position but also to his developing his famous chemical nomenclature. When Guyton was commissioned in 1780 to write the chemical volumes of the *Encyclopédie*, he realized that he had an opportunity to reform the then cumbersome chemical nomenclature. He set forth his reform in 1782 and applied his principles not only in the first part of the *Encyclopédie*, but also in the translations he had made of the works by Bergman and Scheele.

The application of his nomenclature initially was almost exclusively connected with the naming of acids, basis, and salts; the preparation of these substances was not dependent on any one system of chemistry for interpretation and nomenclature, and, therefore, their names could be used with equal convenience by both phlogistonists and antiphlogistonists. However, in 1786 when Guyton started to prepare his sections on *Air* for the *Encyclopédie*, he was not only confronted with the problem of devising a new nomenclature for the chemical substances involved, particularly gases, but also with the necessity of adopting either the phlogiston or antiphlogiston theory, since his names could only apply to one system, not both. He therefore went to Paris to consult with Lavoisier and his disciples about the new chemistry, and it was after a number of months of discussions and convincing experimental demon-

strations that he decided to give up the phlogiston theory (Duveen and Klickstein, 1956).

After his conversion, Guyton became one of the most vigorous advocates of the anti-phlogiston theory. He believed, however, that spite its shortcomings the phlogiston theory had served chemistry well: "Cette hypothèse a été, dans les premiers temps, plus utile que nuisible aux progrès de la chymie; c'est ce que l'on ne peut contester raisonnablement, et j'aurai plus d'une occasion d'en fournir des preuves indubitables; je me bornerai en ce moment à faire quelque liaison entre une multitude de faits épars et d'observations isolées; que ces rapports subsistent, ou plutôt que de nouvelles explications plus directes n'ont servi qu'à leur donner une base plus solide" (In the beginning, this hypothesis was more valuable than damaging for the progress of chemistry; it could not be contested in a reasonable manner, and I had more than occasion to give indubitable proofs for it. I will now limit myself to relate between a multitude of scattered facts and isolated observations, that these relations persist, to which new observations had served to give it a more solid base) (Bouchard, 1938; Melhado, 1983).

Affinity

The concept of affinity was of great importance to the eighteenth century chemists. Under the influence of Isaac Newton (1642-1727) they considered that particles were also capable of exhibiting repulsive and attractive effects. According to Newton the combination of two bodies was the result of the short-range interactions present between them: "And so when a solution of iron in aqua fortis dissolves the *lapis calaminaris* (calamine), and lets go the iron, or a solution of copper dissolves iron immersed in it and lets go the copper does not this argue that the acid particles of the aqua fortis are attracted more strongly by the *lapis calaminaris* than by iron and more strongly by iron than by copper?" (Newton, 1730).

Using Newton's ideas many eighteenth century chemists tried to establish tables on which the different bodies were arranged according to their assumed affinity values. These tables were established on the assumption that the affinity of one body for another was constant. In 1718 Étienne François Geoffroy (1672-1731) was the first to arrange substances in a table of affinities in such a way that any substance displaced from certain of their compounds all others below it in the same column. Geoffroy's ideas and methods were developed by other chemists notably

Pierre-Joseph Macquer (1718-1784) and Bergman. In 1770, many chemists, particularly Antoine Baumé (1728-1804), remarked that the affinities were totally different depending if the compounds reacted at ordinary temperatures or at high temperatures. For example, at room temperature silica was precipitated from its solutions even by weak acids; at red-hot temperature it displaced the strongest acids from their compounds.

Guyton accepted and taught the prevalent theories about affinities and developed them in two directions: he studied the way in which reactions were caused by the mutual attraction of the ultimate particles of matter, and he tried to obtain numerical values for the affinities between different substances.

Guyton first expounded his theory of the cause of affinity in 1771 in the *Essai Physico-Chymique Sur la Dissolution et la Crystallization, Pour Parvenir à la Explication des Affinités Par la Figure des Parties Constituants des Corps* (Guyton de Morveau, 1772), the second long essay in *Disgressions Académiques*. It was a serious attempt to rationalize the concept, but his wrong position regarding the existence of phlogiston led him on the wrong track when trying to explain why metals increased in weight on losing phlogiston.

Guyton followed Newton's ideas and advanced the theory that chemical affinity between two substances was caused by the mutual attraction of their constituent particles (*parties constituants*, the ultimate parts of matter). The idea of assimilating all chemical operations to the dissolution phenomenon was not completely new, it had been presented many previous publications, particularly in the book *Elementa Chymiae* (Elements of Chemistry) published by Herman Boerhaave (1668-1738) in 1732.

The title of Guyton's memoir reflects his beliefs that from a study of the phenomena of crystallization it would be possible to infer the shapes of these particles as well as to calculate the forces of attraction. The mutual attraction between the ultimate particles of different kinds of matter would lead to dissolution, and a chemical change was possible only as a result of such a solution. Therefore, each chemical operation required a *solvent* and a *base* or dissolved substance. Following Newton all bodies were attracted to the centre of the earth, but this attraction disappeared when a body was put in a medium denser than itself or when it was attracted more strongly to a neighbouring body. In the second case it would adhere to the neighbouring body and the

two would then gravitate together like twin stars. The mutual attraction between bodies was responsible for division as well as adhesion since the adhesion of two bodies was broken when one of them was attracted more strongly by a third. Dissolution occurred when the attraction between the particles of the solvent and the particles the substance was stronger than that between the particles themselves (Guyton de Morveau, 1772, 1778). According to Guyton, dissolution was an operation by which substances were weakened in order to present an exact gravitation rapport with the dissolving fluid. Division was the first condition for dissolution and equiponderance was the second. The mechanism of dissolution was based on the attraction of the solute particles by the solvent and the movements caused by such an attraction. Equiponderance was the necessary condition and could be destroyed by the addition of other substances. For example, addition of alcohol to a water solution of sodium carbonate resulted in precipitation of the salt because the alcohol had diminished the density of the broth. On the other hand, oil could be made equiponderant with the help of soda (Smeaton, 1963).

Guyton's belief in the existence of phlogiston led him to a curious statement regarding the rate of dissolution: The process was faster when the dissolved substance was itself a compound. Since a metal consisted of phlogiston united to a metallic earth, dissolution of the metal in an acid resulted in the union of the earth with the acid and liberation of phlogiston, which, being less dense flew off. The heat produced during solution was a necessary consequence of the collisions between particles.

Twenty solvents were recognized: The basic ones were three: fire, air, and water. Fire was a substance essentially fluid by which other materials enjoyed of this property. Fusion, calcinations, vitrification, and reduction, were dissolutions realized by fire. Combustion and oxidation were dissolutions realized by air. The remaining solvents were the known nine acids; the three alkalis; four oily substances, spirit of wine, ether, essential oil, and fatty oil; and mercury, a metallic fluid.

In present terms, a reading of Guyton's theory indicates that he had reached two well-known consequences: the constancy of the crystalline shape and the formation of complex crystals.

An important observation is that in his early studies of affinity, Guyton did not consider the effects of temperature, but in 1789 he stated, as one of the

laws of affinity, that a change in temperature could make an affinity ineffective, or could alter the speed with which it acted (Guyton de Morveau, 1800, 1804).

Nomenclature

According to Guyton by 1760 chemists, manufacturers, and physicians were familiar with a very small number of compounds. Six acids were known, together two soluble earths, eleven metallic substances, and about thirty salts. Although the actual number was larger, it was still a small fraction of what would be known by the end of next century. The name of each compound was related to their aspect, their origin, a typical property, or the name of its discoverer: vitriolic oil (sulphuric acid), *laine philosophique* (zinc oxide), *sel d'yeux d'ecrevisses* (salt of crayfish eyes, calcium acetate), Epsom salt (magnesium sulfate), sedative salt (boric acid), and Libavius fuming liquor (tin tetrachloride). The increase in the number of new compounds that took place in the following twenty years created an inextricable confusion in their identification and the appearance of many synonyms. For example, carbon dioxide was known as wild spirit (van Helmont), fixed air (Priestley), aerial acid (Bergman), chalk acid (Bucquet), mephitic acid (Sage), and carbon acid (Lavoisier). In the words of Guyton: "Those who first saw vitriolic acid and fixed vegetable alkali in a certain degree of concentration, gave them the denomination of a substance which they resemble only in their consistency; hence the names *huile de vitriol* and *huile de tartre*. Equally false analogies led to the names *beurre d'antimoine*, *beurre d'arsenic*, *lune cornée*, *plomb cornée*, etc. Uncertain and variable colors produced the names *foie de soufre*, *safran de Mars*, *éthiops*, kermes mineral, etc. Now let us ask whether it is possible to find our way in this chaos, and whether the understanding of such a nomenclature is not more difficult than the understanding of the science itself" (Guyton de Morveau, 1782).

Many chemists had tried to put some order in this anarchic situation by grouping together substances that had the same kinship, particularly the salts derived from the same acid. On this basis, Baumé and Macquer created the classes *vitriol* for the different sulfates and *nitre* for the various nitrates. Jean-Baptiste Bucquet (1746-1780) and Antoine-François Fourcroy (1750-1809) went a step farther and designed the salts by the name of their acids and metal.

To Guyton must be given the credit of being able to propose the first general nomenclature that led eventually to the one accepted nowadays. In his famous memoir on the subject (Guyton de Morveau, 1787) he established the following principles for assigning a name to a substance: (a) it was necessary to give a name to each substance and avoid the use of circumlocutions. For example, the name *sel marin a base de terre pesante*, would become *muriate de barote* (barium nitrate) and *sel de succin retiré par la cristallisation* would be named *l'acide succinique cristallisé* (crystallized succinic acid); (b) the name of a compound should reflect the composing parts and characterize it clearly. For example, the name *acète de plomb* (lead acetate) was clearly better than *sugar of Saturn*, and *muriate d'argent* (silver nitrate) better than *lune cornée*; (c) In the case of substances of unknown composition, it was preferable to assign a name having no meaning than any other that would convey a false idea; and (d) It was recommended to base the new names on the roots of old languages, such as Latin.

Guyton's proposal's of 1782 were concerned almost exclusively with the naming of acids, bases, and salts; the substances with which he was chiefly concerned in the first half-volume of the *Encyclopédie Méthodique*. But in 1786, when he started to prepare the article *Air* for the second-half volume, it became necessary for him to choose the nomenclature of the different kinds of air (the different gases) and their compounds, and this choice depended on which theory of their nature he adopted.

According to Guyton the most important decision was that regarding the names of the simple substances, those defined by Lavoisier as "all substances that we cannot decompose; all that we obtain in the last resort by chemical analysis", for the names of compound substances were determined by those of their components. These substances were divided into five classes. The first class included *lumière*, *calorique*, *oxigène*, *hydrogène*, and *azote*. *Oxygène* received its name because it was thought to be the common constituent of all acids (*ó*, acid), and *hydrogène* because it was the only gas that gave water on combustion. The naming of the third gas presented some difficulty, because it was known to be a constituent of an acid (nitric acid) and a base (ammonia), and it was thought to be undesirable to refer to only of these properties in its name. It was finally decided to refer only to its property of not supporting life and the name *azote* was chosen. The second class con-

sisted of the acidifiable bases or radical principles of acids, the simple substances, which were thought to combine with acids to form compounds. For these Guyton adopted a completely uniform system, which included the difference between the states of oxidation, for example, *-ique*, *-eux*, with *-ate* and *-ite* for the corresponding salts. Substances previously named as *foies*, *hépars*, or *pyrites*, which were now known to consist only of a metal combined with sulfur, were named *sulfures*, and the corresponding compounds of carbon and phosphorus were called *carbures* and *phosphures* (Smeaton, 1954).

Little change was made in the naming of the metals, but it was now recognized that they were simple substances and not composed of phlogiston combined to an earth. Their compounds with oxygen were called *oxides*.

Guyton's ideas were accepted and supported by most of the chemists of his time (such as Bergman, Berthollet, Crell, Fontana, Fourcroy, Kirwan, and Macquer) and attacked by a few others [such as Jean-Claude La Métherie (1743-1817) and Balthazar-Georges Sage (1740-1824)] on the arguments that it

was "barbarian, incomprehensible, and without etymology". Eventually Guyton's classification became essentially official after it was presented to the Académie des Sciences as the book *Méthode de Nomenclature Chimique* (Guyton de Morveau, 1787), signed simultaneously by Guyton, Berthollet, Fourcroy, and Lavoisier. As Bouchard says (Bouchard, 1938), opposition to Guyton's classification was really another aspect of the fight against Lavoisier's ideas.

Guyton's treatise went through many editions and was translated into many languages (Figure 2).

The composition of water

On December 8, 1782, the British scientist Joseph Priestley (1733-1804) wrote to James Watt (1736-1819) that he could "readily convert water into permanent air by first combining it with quicklime and then exposing it to a red heat", and on the same day he reported his discovery to Josiah Wedgwood (1730-1795), adding that the air was "little worse than that of the atmosphere", though it contained a small proportion of fixed air (carbon dioxide). Richard Kirwan (1733-1812), another famous British scientist, was extremely sceptical about this result and expressed his opinion very bluntly in a letter to Bergman on January 20, 1783: "Doctor Priestley believes he had changed water into air. I believe none of it" (Carlid and Nordström, 1965). To confirm his suspicions Kirwan wrote to Guyton and requested his help in repeating Priestley's experiments and confronting the results. Guyton accepted the request adding the remark that Priestley's results departed far from generally accepted ideas and that it would be necessary to be very careful before admitting them to be true. Only experiment could provide the proper answer (Smeaton, 1968).

In a first series of experiments Guyton confirmed that large amounts of air were produced when water combined with quicklime was heated to redness in an earthenware retort. From two ounces of quicklime and one ounce of water he collected 252.67 in³ of water, 14.67 in³ of which was fixed air (accidentally present in the lime) and the remainder was very similar to common air. Guyton also agreed with Priestley that there was no evolution of air when an ordinary glass retort was used. Priestley had also found that air was produced in a glass retort that had lost its polish. To prepare such a glass Guyton heated a mixture of fluorspar and sulphuric acid in the retort. From four ounces of lime and two of water he

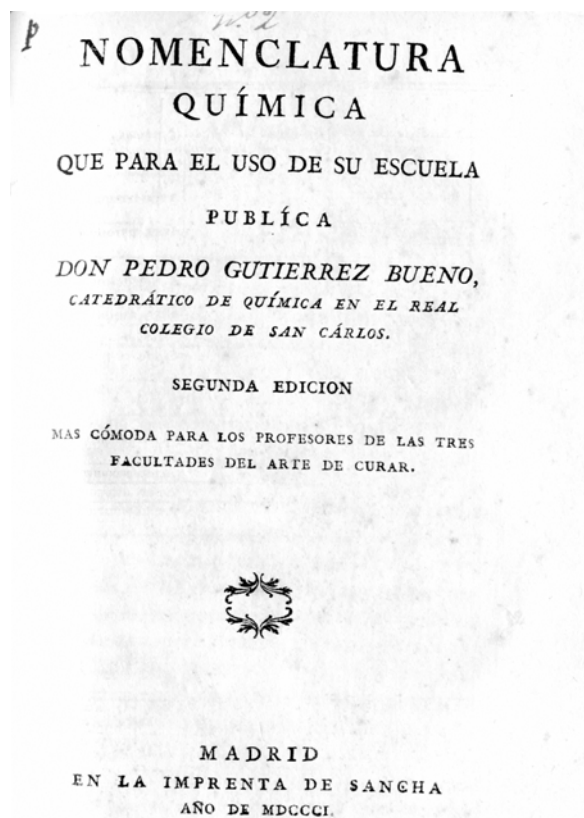


Figure 2. 1801 Spanish translation of Guyton de Morveau's book.

obtained only 51.25 in³ of air, less than the volume of the retort and attributable to thermal expansion. The last result contradicted Priestley's and gave Guyton the clue to what was happening: atmospheric air was penetrating the equipment. He now repeated his experiments this time using an ordinary retort completely coated with an opaque and heat resistant clay covered with powdered glass and borax. This time he obtained an amount of air was smaller than the volume of the retort, however strongly he heated it. In other words, whenever Priestley found a large volume of air it had entered from the outside the retort; earthenware was always porous and Priestley's roughened glass must have been treated mechanically, not chemically, with an abrasive that formed minute cracks, which, although invisible, were large enough to let air pass through the pores or cracks whenever the retort ceased to be filled with a fluid capable of resisting it (Smeaton, 1968).

Guyton reported his findings to Kirwan and his conclusion that Priestley's results were due to faulty experimentation and not to a deviation from known chemical principles.

Eventually Priestley repeated his experiments and confirmed that the air he had found previously had entered the retort through pores in the earthenware and was not a result of the decomposition of water (Priestley, 1783).

On the nature of steel

For alphabetical reasons, Guyton's first entry in the *Encyclopédie Méthodique* (Guyton de Morveau, 1786) was on steel (*Acier*). This article occupies pages 420 to 451 of Volume I and constitutes a critical examination of the phenomena and the existing theories about the manufacture of steel from iron. It contains a summary of the work done by Bergman and Sven Rinman (1720-1792) and a report on new experiments done by Guyton himself. Guyton agreed with Bergman that plumbago (carbon) alone, as a substance that alloyed with iron, was essentially responsible for the differences between wrought iron, cast iron, and steel. The entry also contains a section in which Guyton discusses that roles played by caloric, phlogiston, and the newly discovered vital air, and shows that they are not responsible for the distinction between iron and steel.

Guyton pointed out that the three kinds of iron differed in their content of plumbago (carbon), wrought iron being pure metal, cast iron contained most plumbago, and steel a smaller amount. He

suggested that wrought iron takes up plumbago on conversion to steel in the cementation process:

“If cast iron, steel, and wrought iron are dissolved in pure vitriolic acid diluted with two parts of water, with the aid of a little heat, the wrought iron will be completely dissolved, a black powder will separate from cast iron and from steel in different proportions, but always in very perceptible quantity and always more abundantly from the cast iron than from the steel. A great number of very thin black flakes are seen floating in the liquid. After one day, the piece of cast iron is found to have the same shape as originally and appears to have hardly decreased in volume, although it has often lost more than one-third of its weight. It is already covered with rust, and beneath this rust lays black powder still adhering to the cast iron, although it is easily detached. There are important differences between the black powder that adheres to the metal and the flakes that have separated from it. The powder is a true *ethiops* (in the old days, black oxide of iron, iron carbide in modern terms) that is very sensitive to the magnet, dissolves in acids and rusts if left in open air. The flakes have none of these properties. There is therefore a substance in cast iron and steel that is not given in the analysis of wrought iron and that is neither *ethiops* or *saffron of mars* (ferric oxide or ferric hydroxide in modern terms). Cast iron and steel really do contain a perceptible amount of a substance that is not iron in the metallic state and that has the properties of remaining united with iron. How does plumbago act in the conversion of iron into steel? How do the plumbago and charcoal-turned-plumbago penetrate the entire mass of the bars of iron during cementation? Finally, how can such a small quantity of plumbago produce such so great a difference between iron and steel? The increase in weight of steel and the products of its analysis show are a direct proof of the change in composition of iron on its passage to steel.”

In connection with this research it is appropriate to mention Guyton's work on diamond. Guyton showed that wrought iron could be converted into steel by heating in contact with diamond; he also considered diamond to be the only pure form of carbon, charcoal being “carbonous oxide”. His ex-

periments on the combustion of diamond indicated that one part of diamond combined with 4.55 parts of oxygen; since it had been found that one part of charcoal combined with 2.86 parts of oxygen, this would indicate that one part of charcoal consisted of 0.688 of carbon and 0.312 of oxygen. ▀

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