Balthasar-georges sage

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RESUMEN Baltasar-George Sage (1740-1824), un químico e ingeniero de minas conflictivo y uno de los últimos partidarios de la teoría del flogisto y de la antigua nomenclatura química, realizó un gran número de investigaciones metalúrgicas. Descubrió el ácido hipofosfórico y el ferrocianuro de potasio sólido. Su mayor triunfo fue la fundación de la Escuela de Minas de Paris.

ABSTRACT Baltasar-George Sage (1740-1824), a conflictive chemist and mining engineer, and one of the last supporters of the phlogiston theory and the old chemical nomenclature, carried on a large number of metallurgical researches, discovered hypophosphoric acid and solid potassium ferrocyanide. His most achievement was the foundation of the School of Mines of Paris.

LIFE AND CAREER[1-7]

In his biography[3,4] Balthasar-George (Figure 1) wrote that he was born in Paris, on May 7, 1740, the second of the three children of Marie-Ursule des Cloîtres and François Sage, a pharmacist, son of a notary of family name Sapienti. He had an elder brother, Daniel-Jacques, born in 1737, and a younger sister, Marie-Ursule. According to Balthasar his father believed in science and that it was more valuable to build your own fortune than to inherit it. Since the economical resources of the family were scarce, he received his first education at the famous Collège des Quatre Nations [1] (*Collège Mazarin*, one of the colleges of the University of Paris), where he finished his studies of rhetoric at the age of 13, a year after the death of his father. At the time of her husband's death, the mother decided that the elder son. Daniel-Jacques would help her in managing the family pharmacy, while Balthasar-George would complete his studies at Mazarin. After graduation, Balthasar-George became an accredited pharmacist [2] and followed the public courses given by the Abbot Jean-Antoine Nollet (1700-1770) (Physics), Bernard de Jussieu (1699-1777) (Botany), Raphael Bienvenu Sabatier (1732-1811) (Anatomy), and Guillaume François Rouelle (1703-1770) (Chemistry). He used to repeat the experiments he had observed in class in a small laboratory that he had built at home. When he was 16 years old, he had a bad case of poisoning with vapors of mercuric chloride, which led to extensive bleeding. He recovered after being subjected to

Fig 1. Balthasar-George Sage (1740-1824).

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[1] A nation (Latin: natio meaning being born) are regional corporations of students at a university, once widespread across Europe in medieval times, they are now largely restricted to the ancient universities of Sweden and Finland. The students, who were all born within the same region, usually spoke the same language, and expected to be ruled by their own familiar law.

[2] According to Dorveaux1, there is no documentary evidence proving that Balthasar-George Sage was recognized as apothicaire privilégié or as maître apothicaire of Paris.

twelve bloodletting operations during three days. This accident did not deter his taste for chemistry because he had learned that France was spending 37 million livres for importing raw materials needed by industry. At the age of nineteen (1760), he began to give free classes on Chemistry and the techniques of assaying, in a laboratory he built with a loan from some rich students. It was at that time he begun building the extensive mineralogical collection, which would become quite an attraction and bring him friends and enemies. In his biography, Sage mentions that some of his French and foreign colleagues sent them some important samples, for example Peter Simon Pallas (1741-1811) sent his a piece of the meteorite he had discovered in Siberia. Eventually Sage's collection became the *Musée des Mines* at the Mint.[3,4]

In 1769, he published his first booklet, *Examen Chymique de Différentes Substances Minérales*[8], which was followed by a large number of short papers on mineralogy. His numerous publications in the area of mineralogy, as well as his close relations with the King Louis XVI (1710-1774) and his finance minister Charles Alexandre de Calonne (1734-1802), led him to be elected to the position *adjoint chimiste* (1770) at the *Académie des Sciences* available after the death of G. Rouelle, replacing Louis-Claude Cadet de Gassicourt (1731-1799) who had been promoted to *associé*. Sage was then 30 years old. He was promoted to *associé* on December 19, 1777, again replacing Cadet who had been promoted to *pensionnaire*. On March 1784, after the death of Macquer, Sage was promoted to *pensionnaire chimiste*.[7] Sage proposed, and eventually obtained (1778), the creation of a chair in docimastic mineralogy, which was installed at the Mint. This appointment was accompanied by an annual stipend of 2000 livres. Some of his most famous students included the crystallographer Jean-Baptiste Romé-de-l'Isle, the surgeon Jean Demeste (1743-1783), and the chemist Jean-Antoine Chaptal (1756-1832). Sage's activities at the chair and his many political relations led to the foundation of the *École des Mines* (1783), with Sage as his first director. The institution was housed at *Hôtel de la Monnaie* (Mint) and provided with two Chairs, one on mineralogy and assaying (Sage), and the other on the practical aspects of mining [filled by Jean-Pierre François Guillot-Duhamel(1730-1816)]. Sage served in these positions until he came into disgrace with the political leadership of the Revolution; lost all his titles, and was imprisoned for a short time (1793-1794). Under the Directory, he was partially rehabilitated and as a result, he was admitted as a *non-resident associé* of the section Natural History and Mineralogy of the First Class of the Institut National (1796), and five years later, promoted to resident member of the same section (1801). In 1817, he was awarded with the Cordon de Saint-Michel. Todericiu writes that after this election, Sage abandoned all scientific activity and involved himself in a long series of administrative disputes in order to recover his lost property and positions.[7]

Sage was married to Philippine-Augustine Julia Piedchin; they had two adopted daughters; the three originating from Santo Domingo. In 1818, aged 78, he fell and broke the neck of the femur; an accident which left him ill for a long time. Sage passed away at the *Hôtel de la Monnaie* in Paris, on September 9, 1824.[2]

Sage was a fervent royalist and one of the last supporters of the phlogiston theory. He ardently fought the new chemical nomenclature and Antoine-Laurent Lavoisier's (1743-1794) new chemistry. As a consequence, he became a clear opponent of the Revolution and of the scientific establishment. This led to his downfall and the loss of his positions (Censor Royale, at the Mint, apothicaire-major at the *Hôtel des Invalides*, Director of the School of Mines and professor at the same), pension and income.

From the many documents he wrote fighting for his rights[3-6] we quote the following: *"In 1790 Charles François Le Brun (1739-1824, Duc de Plaissance), President of the Committee of Finance, led the committee to pass a degree ordering me to transfer my collection of mineralogy to the Jardin des Plantes from the Royal School of Mines. By the same decree, I was deprived of his salary as professor of assaying, a chair paying a salary of 2000 francs."* In 1793, during the Terror, the National Assembly approved the Law of Suspects, directed towards *"those who by their conduct or by their relations, either by their words or writings, have shown to be partisans of the tyranny or federalism and enemies of freedom"*. As a result of his close relations with the King Louis XVI and his wife Marie Antoinette (1755-1793), Sage "*was thrown into prison and confined in an infectious dungeon; it was in this sepulchre of the living where he first begun to lose his sight (he could no longer distinguish colors or forms). After paying a hefty fine, I was put in a Maison de Sainté, under the inspection of Antoine Quentin Fouquier-Tinville (1746-1795), the public prosecutor) (the accusation was that I had received the Queen and Royal family at my country house). I was then deprived of his salary of 6000 francs as Commissioner of the Assaying of Metals. Haüy and Vauquelin were appointed to replace me. I was also ordered to transfer my collection from the Jardin des Plantes to the Hôtel des Mines. In 1797, the Executive Directory, just to repair part of the wrongs I had suffered, awarded me a pension from the funds of the Ponts et Chaussées. Eventually Chaptal, while serving as Minister, suppressed my pension …The Minister Montalivet told me once: "They are all against you". I answered: I am stronger than they are because adversity has not forced me to change my principles"*. According to Sage, all the measures taken against him had deprived him of an annual income of about 24000 francs.[3-5]

From 1766 on. Sage had begun publishing the results of his many projects on metallurgy, chemistry, agriculture, chemical nomenclature, meteors, galvanism, etc. In 1773 he already published a booklet detailing 27 of them.[9] As an example, the author can mention his findings about malachite;[10] crystals prepared from a solution of a copper salt in ammonia,[11] on mineral coal and peat,[12] about zinc,[13] crystallization of metallic substances,[14] a study and actualization of new preparative methods for Prussian blue,[15] the decomposition of gold fulminant,[16] the discovery of hypophosphoric acid ($H_4P_2O_6$) by exposure of sticks of phosphorus to air under restricted conditions;[17] the preparation of phosphoric acid;[18] a red copper mineral;[19] the industrial production of Prussian red and English red;[20] about bismuth,[21] about oxalic acid,[22] etc. etc.

Several of Sage's most important analytical results were challenged and proved to be wrong by reviews committees appointed by the *Académie des Sciences*, casting doubt on his other findings.

SCIENTIFIC ACTIVITIES

Sage published about 100 papers in a wide variety of subjects: metallurgy, chemistry, medical chemistry, agriculture, chemical nomenclature, meteors, galvanism, etc. A large number of these were also published as booklets. Many of the latter did not mention that he was a member of the *Académie des Sciences* (to avoid requesting the approval of the institution, which would have probably been denied). Usually, the content of his publications reflected his obstinate refusal to accept the new chemistry of Lavoisier and the decline of the phlogiston theory.

Here the author will only address his arguments against the chemical revolution and some of the publications that reflect his staunch views on this subject.

The fight against the new chemistry

Chemical nomenclature

During the eighteenth century, there had been numerous attempts to construct a systematic chemical nomenclature. Louis-Bernard Guyton de Morveau (1737-1816) was in the forefront these efforts in France, suggesting numerous options by which the names of substances could be made simpler and more precise. His most significant ideas were embodied in a memoir of 1782 where he proposed that the names of compound substances should reflect their composition.[23] For example; the name of a salt should indicate the acid and the base, which formed it. Guyton's ideas were accepted and supported by most of the chemists of his time, such as Torbern Olof Bergman (1735-1784), Claude-Louis Berthollet (1748-1822), Carl Justers Ludwig von Crell (1712-1793), Felice Fontana (1730-1805), Antoine-François Fourcroy (1750-1809), Richard Kirwan (1733-1812), and Pierre-Joseph Macquer (1718-1784), and attacked by a few others, such as Jean-Claude La Métherie (1743-1817) and Sage, on the arguments that it was "barbarian, incomprehensible, and without etymology". Eventually Guyton's classification become essentially official after it was presented to the Académie des Sciences as the book *Méthode de Nomenclature Chimique,*[24] signed simultaneously by Guyton, Berthollet, Fourcroy, and Lavoisier. An attachment to this book was scheme of chemical symbols proposed by Jean-Henri Hassenfrantz (1755-1827) and Pierre August Adet (1763-1832).

The logical reform of the chemical language proposed by Lavoisier, Fourcroy, Berthollet, and Guyton de Morveau, did not gain a complete approval of the referees appointed by the *Académie des Sciences* in 1787, Antoine Baumé (1728-1804), Louis-Claude Cadet de Gassicourt (1731-1799), Jean Darcet (1725-1801), and Sage. The three were open supporters of the phlogiston theory and hence they recommended: *"We therefore believe necessary to subject this new theory, as well as its nomenclature, to the test of time, to the impact of experiments, to the doubts it has raised, in short, to the judgment of the public as the only tribunal. Then it will not be a theory; it will become a chain of facts or an error. In the first case it will provide a solid base for solid human knowledge; in the second case, it will go into oblivion with all other theories and systems that have preceded it".*[25]

Sage's scorn of the new nomenclature led him to publish a separate sharp criticism,[26] as well as to express it in several of his memoirs (see below). He opened his book saying that *"it was about after 20 years that men like Bergman, Scheele, Priestley, and Cavendish, had made the everlasting discoveries that had anchored forever the opinion of scientists about the nature of mixtures, fire, atmospheric air, and gases in general, when the innovators, willing to appear as leaders of a sect and to dismiss the rightly famous works that established the healthy basis of physics, believed and succeeded in forging a barbarian and insignificant nomenclature suited to paradoxes that they have decorated with the name Doctrine Française (French Doctrine). All these paradoxes were embodied in the Encyclopédie Méthodique."* [27]

"When the father of the new nomenclature (Lavoisier) addressed the Académie de Sciences, she answered at first that she dealt about facts and not about words. This response did not put off the innovator; he called for help the Sociéte de l'Arsenal [3], where a conciliabule was called on. I was invited to participate in the making of the neological masterpiece. I replied that I would not muddle up, that I regarded the scientific technique as a sacred public fund that

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[3] The group of scientists working at the Salpêtrerie (the gunpowder manufacturing factory).

had to be respected. To me the neologism was true charlatanism; I did not ambition the celebrity of Heraclites, but adhered to Voltaire's feelings, who wrote "if you do not think, create new words, talk big, scatterbrain the fools".

"The conciliabule adopted the nomenclature and thought it to be worth of the new doctrine of the Arsenal that offered only, as will be seen, paradoxes, and a superstition of hypotheses. One can ask how was this nomenclature and doctrine able to propagate? These are the means it employed towards the year 1793 to separate the professors from their chairs and replace them. A person endowed with an apostolic diligence, gave seven lessons per day. At the same time, everyone who was studying was impregnated with the doctrine and nomenclature of the Arsenal; every candidate was admitted to the exams only he was recognized as orthodox. The only teaching books accepted for public education were those that carried the seal of this scientific revolution. In order to keep their positions, professors had to rally under the banner of the all-powerful evangelist (Lavoisier). Regarding myself, I have consistently confronted the current scientific despotism. Loss of my freedom, deprivation of my positions and of my fortune had not convinced me that my doctrine is erroneous. To push forward the idea that a doctrine is incorrect without giving irrevocable proofs is to compromise yourself; proving that the fundamental bases of these doctrine are inadmissible, it is to ruin it".[26]

Sage went on to describe the facts that he felt were irresistible. He started with a discussion of the terms oxygen and hydrogen, which were a fertile source of arguments in favor of the new nomenclature. Scheele's fire air, which was the dephlogisticated air of Priestley, misrepresented as oxygen, was, according to the (our) oxyphiles, the creator of acids, the component of metallic oxides, one of the principles of water, the essence of fire, and the vital principle. Sage added a footnote indicating that the neologists believed that the word oxygen meant acid generator, although its true translation was *son of vinegar*, for the same reasons that Theogène meant son of God, and not father of God, and Diogène meant son of Jupiter and not father of Jupiter. The inflammable gas (hydrogen) of Priestley was represented by the oxyphiles by the word hydrogène, which according to them, expressed water generator, although a literal translation meant son of water. However, how could we consider as water generator a substance it had never contained? Inflammable gas was 12 times lighter than atmospheric acid and the latter was 850 times lighter than water. That is, inflammable air was 1250 times lighter than water. Now, according to Cavendish, inflammable gas corresponded to 1/6 of the composition of water, it turned out that if inflammable gas generated water, then it would be only 1/5100th of its composition. Dephlogisticated air (oxygen) did enter in the making of acids, but assisted in decomposing the phlogiston that neutralized them (here Sage is temporarily correct, in the beginning Lavoisier believed that all acids contained oxygen).[26]

Acidum pingue-acide igné

In 1764, Johann Friedrich Meyer's (1705-1765) published a Chemistry book[28] where he advocated the existence of a principle that was the primitive acid (acidum pingue, fatty or oily acid, fett saüre); a substance that entered in the composition of every natural body, including acids. This acidum pingue was a subtle substance, elastic, similar to sulfur, indestructible, assumed to be an unknown saline substance combined with the matter of fire or light. It was expansible, compressible, volatile, able to penetrate all vessels when heated, and extremely heavy. During the combustion of charcoal, part of it escaped to the atmosphere and a small part combined with the ashes. According to Meyer, the effervescence observed during the reaction of a mild alkali carbonate with an acid, reflected the absorption of the acidum pingue present in the acid. The fact that the reaction of a caustic alkali such as NaOH and KOH was not accompanied by effervescence indicating that the alkali was saturated with acidum pingue, a result demonstrated by its slippery feeling. Acidum pingue should not be confused with phlogiston; the latter turned calxes into metals while acidum pingue calcined metals.

According to Lavoisier, Meyer had let himself to be carried away like everyone who believed to have discovered a new agent, and applied it indiscriminately to everything. Thus, Meyer believed that acidum pingue was present in quartz, glass, and in nitric acid; was the factor that gave burning coal its red color, dissolved carbonates, sulfur, and oils, and gave to fuming sulfuric acid its properties. Acid pingue formed part of the suffocating gas produced during fermentation and combustion and was the basis of air and the main component of the electric fluid.

Meyer's notions were taken up and amplified by Sage; he adopted the concept of acidum pingue, gave it the name of igneous acid (*acide igné*) and discussed it in detail in his book on chemical analysis and the concordance of the three kingdoms.[29] This book was the basis of all the public courses that he had taught during 25 years; he had selected this particular name because he had gathered there all identical substances, which were scattered in many sources. The first part of the book was devoted to the analysis of mixtures and showed that acide igné was the essence of the different aeriform fluids (gases), and with phlogiston generated air, electricity, oils, the principle of metallicity, etc, etc. He also proved that the inadequacy of our means to prepare acids was due to the fact that they derived from elemental acide igné, which by combining inside organized bodies with more or less phlogiston, earth and water, gave place to sugar, oils, and the alkalis they contained.

Among the many properties of the acide igné, Meyer mentioned the following: (a) combined with phlogiston, it became insoluble in water and constituted dephlogisticated air, (b) saturated with phlogiston, formed sulfur igné, oils, and the metallicity principle, (c) unsaturated with phlogiston it formed inflammable gas, (d) it was modified by its circulation inside sanguineous animals and became phosphoric acid, (e) sulfuric acid was a modification of acide igné, (f) modified by putrid emanations it formed nitric and marine acid (HCl), (g) the acid of sugar (oxalic acid), modified by vinous fermentation, converted partially into mephitic acid (CO_2); the remaining part returned to the state of acide igné, which was found in wine oil and in ether; the later became vinegar during acetic fermentation (h) mephitic acid, also called fixed air, was the last modification of the acide igné; it was not altered by chemical agents, but reabsorbed by vegetation, to be returned to the atmosphere as dephlogisticated air (oxygen).[29]

According to Sage, if there was a substance, which deserved the name *element*, it was the one that constituted a principle of every body, a substance that could not be produced and could not be decomposed. Acide igné was such a substance; it was modified when it became part of mixtures, but it was restituted to their initial state and purity by their combustion. Acide igné was the heaviest of all acids; it freed them of their basis and substituted it. It was the principal agent of vitrification. When saturated with phlogiston, it formed a kind of sulfur igné, which combined with metallic earths and constituted the metals. This sulfur igné, which became the principle of a metal, was susceptible to decompose in contact with air. The metal became then part of a calx, which was a true saline combination formed of acide igné and metallic earth. Sulfur igné could be separated from the metallic earths by acids lighter than acide igné; the latter was reloaded with phlogiston and formed non-luminous inflammable vapors.[29]

It is clear from the above that Sage was absolutely bent in trying to discredit the new nomenclature and new chemistry.

At the end of an English translation of Sage's paper on conjectures regarding the formation of metallic galvanism[30], the translator added: *"this paper bears evident marks of the senility of the author. The acidum causticum of Meyer has long been consigned to oblivion among most chemists, and is not likely to be again taken into favour by any attempt of Mr. Sage to bring it once more upon the stage".*

Blue of Prussia

According to Sage, animal acid was different from the acid obtained by deliquescence of phosphorus (phosphorous acid) because it combined with a fixed alkali (KOH or NaOH) forming a neutral salt (animal salt), capable of precipitating iron in the form of blue of Prussia. Animal acid combined with volatile alkali yielding a soluble salt (also named phlogisticated alkali or Geoffroy's soapy alkali) and combined with absorbent earth [which Sage defined as the material remaining after the calcination of osseous material to yield soluble spath.[15]] Both of these salts were not deliquescent. Sage prepared animal salt by heating a mixture of white flux and dried ox blood until it became red like burning coal, and then poured the mixture on distilled water. The filtered liquid was yellowish and alkaline. Treated with acid it effervesced and precipitated a small amount of Prussian blue. Besides the animal salt with an excess of alkali, the solution still contained volatile alkali. The alkali portion could be saturated (neutralized) by digestion with Prussian blue; the latter lost its original color and became red.

Sage believed that his experiments proved that the compound known as phlogisticated alkali was actually a neutral salt composed of fixed alkali and animal acid. The acid was actually phosphoric acid, which decomposed generating sparks and an acrid vapor. During this operation, phosphorus was formed and decomposed rapidly on heating, yielding an acid similar to the sulfuric one, present in the blood. It was composed of sulfur and its decomposition produced sulfur dioxide (sulfurous acid).[15]

According to Sage, most chemists claimed that Prussian blue was not attacked by acids and, if presently assumed, Prussian blue was iron overcharged with phlogiston, then it should be attracted by a magnet and be soluble in acids. All fixed or volatile alkalis had the property of withdrawing the acid present in Prussian blue; the dye lost its color, and the alkalis saturated with animal acid, formed different neutral salts capable of dissolving a small amount of iron and precipitate as Prussian blue, the iron contained in an acid.

Sage ended his paper mentioning that Axel Frederik Cronstedt (1722-1765) had been the first mineralogist to report native Prussian blue. Peter Woulf (1727-1808), from the Royal Society of London, provided Sage with a sample of such material, originating from Scotland. Sage experiments on this material showed that in the presence of acids it promptly lost its color and deposited as a brown sulfate. Digestion with diluted alkali also led losing its color and, again, depositing a brown sulfate.[15]

Phosphorous and phosphoric acid

In a paper published in 1777,[18] Sage claimed that the substance named solid phosphoric acid, separated from calcined bones by the method of Carl Wilhelm Scheele (1742-1786), was not actually a pure acid but a combination present as a glass, insoluble in water (animal glass). Macquer had presented such a glass, to the *Académie* under the name phosphoric acid.

Sage took a sample of this glass, thoroughly washed and dried, and then digested it during three hours with a solution of potassium tartrate. He noticed that no change in weight took place. Although the material did not have acid properties, it was clear that it contained phosphoric acid, combined with some kind of alkali, which gave it its vitreous state. Scheele had used the glass to prepare phosphorus by distillation in the presence of charcoal, and Macquer had reported that the amount of phosphorus produced was larger when the initial material had an acid taste and was soluble in water.[18]

According to Sage, Joseph-Louis Proust (1754-1826) had repeated and improved Scheele's procedure in order to obtain a higher yield of phosphoric acid. The bones, calcined to a white state, were dissolved in nitric acid and then treated with sulfuric acid followed by calcium carbonate. The liquid supernatant was separated from the selenite precipitate (calcium carbonate) and evaporated to dryness. The remaining semitransparent acid residue was heated in a crucible and transformed into a white transparent glass that Proust named *phosphoric acid removed from calcined bones*. Sage repeated these experiments and found that Proust's material was identical to the one prepared by Macquer. He then distilled one part of this glass with four parts of charcoal. From the amount of pure phosphorus produced per unit mass of glass used, he deduced that about one six of the original glass was an acid that combined with the charcoal and became phosphorus.[18]

In a following paper, [17] Sage described the "phosphoric acid" produced by the deliquescence of phosphorus and the neutral salts that resulted from the neutralization of the acid with alkalis. The experiments were carried on by putting cylinders of phosphorus inside the upper part of a funnel covered with a cap and letting the *deliquium* drip into a flask. His results indicated that one-ounce of phosphorus yielded three ounces of phosphoric acid. The acid had no smell nor taste and an oily touch. Exposed to fire in a crucible, it evaporated according to the relative amount of phlogiston it contained, releasing very acrid white fumes, and leaving in the vessel, a semi-transparent white and deliquescent mass. Direct exposure to fire resulted in the release of garlic odor, melting with sparkles, and catching fire with noise, while releasing very acrid fumes smelling like marine acid (HCl). According to Sage, the vapors were a volatile subtle phosphoric acid, which was related to phosphoric acid as sulfur dioxide was to sulfuric acid. Burning of the phosphorus left a red mass half as dense as the original phosphorus, containing very concentrated phosphoric acid and non-decomposed phosphorus. Left in contact with the air, this mass turned partially into very heavy acid liquor, smelling like phosphorus.[17]

Sage prepared and described the properties of the neutral salts resulting from the reaction of the acid with potassium tartrate, sodium hydroxide, ammonia, and absorbent earth. He concluded that the acid resulting from the deliquescence of phosphorus was different from the one preparing by burning the phosphorus since Lavoisier had found that all the salts prepared by the second process were neutral and deliquescent.[17]

In two additional short papers, Sage described a procedure for transforming opaque, yellow, or red phosphorus into a white-lemon colored transparent variety[31], and the dissolution of phosphorus in alcohol.[32] The change in color could be easily achieved by heating the material under water, for about one hour. The resulting white phosphorus floated in water because of its low density; it had a pulverulent structure, could not be melted, was hardly luminescent in the dark, and little soluble in alcohol. The alcoholic solution was colorless, had an unpleasant smell, and burned in the dark with a green color, the same as melted phosphorus.

Dead Sea water

In 1778, the Académie des Sciences commissioned Macquer, Lavoisier and Sage, to make an analysis of samples of water from the Dead Sea, which had been collected by the Chevalier Toles in two well-closed glass bottles and brought to the geologist Jean Etienne Guettard (1715-1786). According to the report of the committee,[33] the water was clear, without odor, and with astringent, sharp, bitter flavor. The smallest of the bottles was found to contain a cluster of regular crystals of marine salt (NaCl), formed from the water itself and proving that the liquid was saturated in this salt. Macquer *et al.* first determined that the specific gravity of the sample, relative to distilled water, was 1, 240, 619 : 1, 00, 000, and commented that this value was larger than any other known in the mineral world. The high density was the reason why the bitumen of Judea floated on the Dead Sea water, while it precipitated to the bottom of common seawater.

A 5-pound sample of the water contained in a glass capsule was now evaporated to dryness, using a sand bath, and yielded 5 ounces of crystallized common salt, not quite free from a small amount of an earthy earth, which could be totally separated by crystallization. After a series of chemical treatments with alkali, concentrated sulfuric acid and crystallizations, they concluded that one quintal (100 pounds) of water contained about 45 pounds of salt, of which

6.5 were common salt, 16.5 a calcareous chloride, and 22 a magnesium chloride. In the final paragraph of their publication Macquer et al. remarked that *"we end this analysis noting that the water of the Asphaltite lake does not contain even one atom of bituminous substance; it is without foundation that several authors have attributed to bitumen the bitter and disagreeable of seawater or similar waters; this bitterness is proper of marine salt of calcareous base, and especially of the magnesium base of Epsom salt".*[33]

In a paper published in 1809, Martin-Heinrich Klaproth (1743-1817) indicated that Macquer's results meant that 100 parts of Dead Sea water contained 22.786 parts of magnesium chloride, 16.339 parts of calcium chloride, and 6.250 parts of sodium chloride, Klaproth analyzed another sample of the water and concluded that the corresponding amounts were 24.20 parts of magnesium chloride, 10.60 of calcium chloride, and 7.80 of sodium chloride.[34]

Copper-tin

In order to try to solve the monetary deficit, the *Assemblée Nationale Constituante* decreed in 1789 that all the ecclesiastical property should be put at the disposition of the Nation; as a consequence many churches fell in disuse and a large number of bells came into the market and with them the interest in the large quantity of copper available in the form of bell metal, an alloy containing 20 to 25 % of tin. Several possibilities were considered for their use: to sell them as such, to separate the components or to alloy them with a certain amount of copper in order to make them ductile enough so that they could be used to manufacture cannons, coins, or statues.[35] Many French chemists looked for the answer. The most important contribution to the subject was made by Fourcroy[36] and Bertrand Pelletier (1761-1797) alone[37] and in collaboration with Darcet[38]. Fourcroy's approach to the problem[36] was in two different directions based on the variable affinity that oxygen has for metals. In a first set of experiments, he studied the action of hot air on an artificial alloy, made of 80 % wt. copper and 20 % wt. tin. In a second series, he used the metal of the bells and heated it in a crucible in the presence of air until the increase in weight showed that sufficient oxygen had been absorbed, to convert all the tin into oxide. Analysis of the resulting product showed that oxygen had actually combined with both metals. Consequently, he now heated the molten metal in a closed crucible, avoiding the possibility of further absorption of oxygen. During this second heating stage, the copper oxide was reduced by the unreacted tin and after two to three hours the reaction, was complete, all the tin was oxidized and could be separated from the molten copper. Crushed glass or marine salt were added in order to obtain refined copper and separate the tin oxide. Fourcroy also tried to oxidize the tin by heating the alloy with certain metallic oxides; he achieved good separation with black oxide of manganese but litharge and oxide of arsenic were found to be unsatisfactory. In his final report, he remarked that Pelletier had also succeeded in separating the components with the aid of manganese oxide.

According to Pelletier, some people believed that it was impossible to separate pure copper from the alloy. In 1791, he communicated the *Comité de Monnaies* (Currency committee) the results of his experiences, proving that the separation was feasible. His method was based on heating molten bell metal with manganese dioxide; the latter being added en small portions during several hours. Manganese dioxide attacked the tin before the copper and gave a good yield: 100 kg of bell metal yielded 75 kg of copper.[37]

The military situation of France in 1793 led to the urgent need of large quantities of copper for manufacturing cannons. Consequently, the Committee of Public Safety decreed the destruction of all church bells and published detailed instructions of both Pelletier's and Fourcroy's methods. Although Fourcroy's procedure was somewhat expensive, it helped provide copper to the revolutionary government during the many wars it held during its existence.

Pelletier's unconditional support of the strong relation between science and Revolution were clearly stated in the introduction to his Instruction: *"All the sciences, all the technologies, all the knowledge possessed by the French at the highest level, must converge at this moment to the strengthening of the Republic, one and indivisible, to the destruction of her enemies, which through an impious war oppose the success of our glorious revolution…Physics and chemistry must contribute their researches to the defense of such a beautiful cause…It is believed that there is a shortage of copper or the available stocks are insufficient to satisfy the requirements for weapons use. Before the necessary research will teach us how to successfully exploit the mines contained in our territory, the chemical art must teach us how to benefit from what is already available. A bell, with which superstition has over loaded churches, offers us a fruitful resource, a kind of mineral abundant enough to satisfy our needs. We have to learn how to separate copper from them; this is the purpose of this instruction".*[38]

Years later, the Class of Mathematical and Physical Sciences of the *Institut de France* commissioned Guyton de Morveau, Louis Nicolas Vauquelin (1763-1829) and Nicole Deyeux (1744-1837) to inform on the procedure used by Anfry and Lecour for extracting copper and tin from the scoria of bell metal. In the report published in 1801,[39] the committee reported that the scoria was discarded as unusable and sometimes used for improving roads or making dykes. Anfry, a graduate of the School of Mines, had developed a dry process that allowed extracting from 30 to 40 pounds of tin and copper per quintal. The process consisted in oxidizing the tin contained in the scoria followed by washing to separate it from the copper. The tin oxide was reduced by mixing it with exactly 1/11th part of charcoal and heating in an air furnace.

The tin thus obtained was purer than that one was presently reduced in Paris. The latter, when broken in an anvil, presented a close grayish grain, similar to that of a mixture of pure tin containing 1/5th part of antimony. This result induced Sage to claim that the tin extracted from bell metal derived its grain from the presence of antimony (see below). The tin prepared by the method of Anfry and Lecour was firmer, had a lower sound and a duller color. When broken, it presented a fine grayish grain, not attributed to its cooling or to the violent heat needed for its fusion. After much testing the committee concluded that these characteristics were caused by the presence of lead. The composition of the alloy was found to be 98 % pure tin, 1 % lead, and 0.2 % copper.

The committee warmly praised the work of Anfry and Lecour, which restored to commerce 1.5 millions of pounds of tin and 2 millions pounds of copper per year, as well a as process for producing tin oxide, which could be used to plate steel.[39]

In 1794, Sage reported his results[40] about the tin, which could be removed from bell metal. The procedures in use (see above) were based on scarifying the tin and part of the copper. The metal was calcined in a reverberation oven, the oxide was spread over the bell metal, kept fused for some time, and the fused metal was run off. Pure copper was obtained in the proportion of 60 pounds per quintal of bell metal. The residue was a black scoria mixed with greenish vitreous matter. Anfry and Lecour's reduction process yielded a bright metal alloy composed of copper, tin and antimony, covered by gray green enamel containing about 25 % of tin. This alloy was heated in a reverberating furnace until it became oxidized as a dirty white powder. The copper was now separated by washing with water, leaving a residue containing an alloy of copper and tin. These two metals were now separated as indicated before.
Sage observed that the tin removed from the scoria was sturdier than pure one since it could be broken, presenting a gray metallic grain not exhibited by pure tin. This property originated from a part of antimony, which the pewterers used to harden the metal. Once the alloy was formed, it was practically impossible to separate the two metals. Based on this information, Sage prepared and inspected alloys containing different percentages of tin and antimony; the results indicated that the one containing 1/6th of antimony presented the same properties as the one obtained from processing the bell metal. According to Sage, although the antimony-tin alloy was more difficult to form into blocks than pure tin, it was more adequate for tinning utensils than the tin employed by the pewterers for manufacturing spoons, etc. According to Sage, the results of his experiments proved that the metal of bells was actually a mixture of copper, tin and antimony.[40]

Amalgamation

In a paper published in 1773, Sage[14] noted that the solution of metallic substances in mercury was different from other amalgams, taking place without effervescence. During this dissolution, almost all metals lost their phlogiston and the part converted into lime (oxide) appeared on the surface of the amalgam, while the portion that had not been reduced to lime, crystallized thanks to the mercury it contained. The crystals were regular and their structure varied according to the nature of the metal. Fire (heat) was necessary to help this operation, where the mercury, so to say, was fixed. The more mercury employed and the slower the cooling, the more the amalgam crystallization was regular. Sage went on to report his results on the characteristics of the process of amalgamation and crystallization of several metals, e.g., silver, and lead, gold, bismuth, tin, zinc, copper, platinum, arsenic, antimony, cobalt, and iron.[14]

Silver, for example, was hard to amalgamate in a mass form with mercury, but did it easily if filings of the metal were triturated with mercury, or using silver precipitated with copper from its nitrate. Sage amalgamated four parts of silver with forty parts of mercury and noticed that a black powder was formed at the surface. Heating the amalgam produced a yellow glass, mixed with a few portions of black silver. On distillation, the mercury passed over, leaving in the flask white porous silver. Repetition of the process produced similar results, no crystals were observed. In a following experience, he subjected the amalgam to a more intense heat and stopped the process after five hours, when about one part of the mercury had distilled over. After cooling, he noticed that the silver amalgam was floating over the mercury and that its bottom part was crystallized in the form of tetrahedral and octahedral prisms. Sage observed that the silver amalgam exposed to fire crackled when the mercury broke the crystals to vaporize, but no explosion and phosphorescence were noted. He remarked that the crystals were similar to those of virgin silver, found in Peru and Sainte-Marie (in northeastern France), known as dendrite silver or vegetation silver. The crystals contained eight ounces of mercury per ounce of silver. Sage also described his procedure for manufacturing vegetation silver (tree of Dianne) starting from silver precipitated from its nitrate.[14]

Amalgamation of gold, tin, zinc, bismuth, and lead, showed that the pertinent crystals contained six, three, two, and one part of mercury, per part of metal, respectively.

In a later publication[41] Sage reported the fulmination of gold crystallized by means of mercury. After preparing a gold amalgam using the procedure described above, Sage separated the gold crystals, put them in a crucible, and then into a furnace. Almost immediately a slight noise was heard, similar to the bursting of potassium nitrate, followed by a strong explosion accompanied by lively light and generation of a gray smoke of mercury condensed in the air. Inspection of the contents of the crucible showed the presence of most of the gold, finely divided. In 1773, he had observed that the silver amalgam exposed to fire crackled when the mercury broke the crystals to vaporize, but no explosion and phosphorescence were noted.

Treatment of asphyxia

One of the several curious books that Sage wrote outside the fields of chemistry and metallurgy, describes his experiments on the use of ammonia as a remedy in the cure of asphyxia, and about its advantageous effects in the treatment of viper bites, rabies, burns, and apoplexies.[42] Taking another shot against the new nomenclature, he used the name volatile alkali fluor instead of ammonia. Already in the first page, he wrote that he used the word *fluor* because volatile alkali was always in the form of a *fluid*.

In the introduction, he stated that the many experiments he had made to determine the cause of asphyxia (apparent death) had also taught him that ammonia, far from being looked upon as an accessory or stimulant in the treatment of such cases, on the contrary, should be used in preference to any other medicine. He cautioned that ammonia would only act efficiently only for diseases caused by an acid, such as the ones acting on the lungs and led to asphyxia, the ones present in the bites of vipers, ants, gnats, wasps, etc. A curious advise for preventing contagion or diseases that could affect people living in hot and marshy countries was *"to be well rubbed before a clear fire morning and evening, and at the same time to air well the clothes because the acid exposed from combustible bodies purifies the atmosphere and destroys the contagion which may get into the body, or remain in the clothes"*.[42]

After describing the properties of ammonia, Sage added a footnote indicating *that "volatile alkali is compounded of a phosphoric acid, an absorbent earth, and an oily and phlogistic matter, to which it owes its smell "* (!). Then he went on to describe the asphyxia, produced by the fixed air (CO_2), released during vinous fermentation. Once again, he criticized the new nomenclature, stating that fixed air was a name improperly given to a volatile acid, to which he had given the name *marine volatile acid*, and due to its deleterious properties, could be called *mephitic acid*. Sage indicated that the destructive action of the pretended fixed air upon animals was more or less rapid according to the advance of the fermentation. Although this acid extinguished lights (of a candle) equally strongly at the beginning and at the end of the process, it was not equally capable of suddenly terminating the life of animals immersed in it. In this situation, asphyxia was characterized by the sudden privation of the pulse, of respiration, of feeling and motion. These phenomena preceded death occasioned by the mephitic acid and acid effluvia released by burning charcoal, fermenting liquors, etc, etc.[42]

Sage assumed that asphyxia was the result of the action of fixed air upon the lungs. To prove this assumption, he conducted experiments on quadrupeds, birds, insects, and amphibious animals. An interesting result was that frogs resisted the action of CO_2 longer that any other animal. Sage assumed that the reason was that frogs were amphibious and thus required less air to stay alive. Inspection of the lungs of dead frogs indicated they were distended and highly dilated, and had a very pungent savor. After chewing (!) some tissue, Sage detected a slightly salt taste. The time it took the animal to die was about proportional to its size. Subjecting the animals in an asphyxia state to the action of vinegar vapors resulted in death and not in revival.[42]

Sage went on to discuss the actions of mephitics, which he defined as the invisible and suffocating vapors found in caverns (such as the Grotto del Cane near Naples). These gases were either acid or inflammable. The latter caught fire only when brought into contact with a flaming body. Sage claimed that mephitics were composed of volatile phosphorus separated from iron or zinc by the action of sulfuric acid (hydrogen). Once again, ammonia was able to neutralize their asphyxiating action. Hence, it would an act of humanity to give every miner a bottle of this alkali.[42]
Additional experiments proved that the gases released by burning coal were a mephitic acid similar to the one released during fermentation, which killed animals very fast (here he was considering CO, without knowing its existence). According to Sage, the *"produce of vegetable substances, modified by fire, is a species of sulfur composed of phosphoric acid, absorbent earth, a small amount of iron, and a substance produced by burnt oil, which gives it a black color"*.[42]

The following sections of the book were devoted to show that ammonia was the proper medicament to use to revive people who had drowned, to neutralize the poison of snakes, the puncture of insects and rabies (!). In the case of suffocation caused by drowning, the cause of the phenomenon was not the water swallowed or introduced into the lungs, but merely the stoppage of respiration. Hence, according to Sage, the portion of the air remaining in the lungs decomposed; the mephitic acid generated stopped the action of the organ, with the resulting asphyxia. The volatile alkali combined with the acid, forming a non-injurious mixture; the spasm stopped and the external air entered the lungs without difficulty. Sage tested his hypothesis by drowning different animals and then having them inhale ammonia. In almost every case, the animal came back to life.[42]

Sage recommended that the bite of animals suspected of rabies, should be treated immediately with volatile alkali and the victim be given to drink an aqueous solution of ammonia. This treatment should be continued for three days. This subject was also discussed in two additional papers.[43,44]

Chemical analysis mistakes

In several opportunities Sage reported some unusual analytical results, which where rebutted by other chemists and led the *Académie* to appoint a committee to decide the issue. In every ocassion the committee decided against Sage. Here we describe two well-known incidents.

Gold in vegetable cinders

Many chemists in the 17th century had reported that most soils that cover the earth, as well as vegetables, contained a small amount of gold. On May 23, 1778, Sage read a memoir to the *Académie*, reporting new information of the subject.[45] He found that one quintal of calcined garden soil contained 2 ounces and 44 grains of gold (63.5 g), common calcined soil contained 1 gross and 56 grains (6.8 g), ashes of wheat contained 4 gross 12 grains, and beech wood ashes, 2 gross 36 grains. Sage, believed that this was a surprising finding, because we were not talking about a few atoms of gold distributed everywhere, a phenomenon that proved the prodigious divisibility and indestructibility of this metal, but about an amount large enough to justify the exploitation of a large part of the surface of the globe. It meant that this metal was a sensible part of the terrestrial soil or it was a product of vegetation.[46]

Louis-Léon-Felicité (1733-1824), Count of Lauraguais, repeated Sage's experiment and obtained completely different results, which were afterwards confirmed by Darcet and Hillaire-Marin Rouelle (1718-1779), two well-known chemists. Given the economical possibilities of Sage's results, the *Académie* charged the Class de Chimie to carry on additional experiments to clarify the difference in results from Sage and de Lauraguais. A committee formed by Macquer, Chaptal, Lavoisier, Baumé, Jean-Baptiste-Marie Bucquet (1746-1780), and Claude-Melchior Cornette (1744-1794), was charged with carrying on the task.[46]

Sage's procedure consisted in melting in a crucible a mixture of the ashes with minium (red lead, Pb_3O_4), black flux (finally divided carbon and potassium carbonate), and carbon powder. Below the resulting scoria was present a lead globule, from which the gold was separated by cupellation. The members of the committee repeated the experiments following exactly the procedure described by Sage, After many trials the committee concluded as follows: (a) the quantity of gold removed from the reaction of minium with the ashes, was infinitesimal and small. It did not excess one or two grains per royal quintal; an amount very different from the 300 grains or 4 gros 12 grains per quintal (48.95 kg) that Sage had reported in his memoir; (b) the experiments seem to prove that part of this gold was present in the minium, so that the actual amount present in the ashes was even smaller; (c) the committee was quite confident to conclude that the infinitesimal amount present in the ashes came mostly from the minium; (d) it seemed that Sage had accidentally employed a minium richer in gold than the one commonly available in the trade; (e) finally, that in quantitative analysis it was extremely important to treat the minium and the lead that served as blanks, in the same way and at the same temperature that the ones used on non refined lead. According to the committee, these were the reasons why Sage and other chemists had found in the ashes an amount of gold larger than the one actually present.[46]

Two years later (1780), Sage published a book of the art of assaying gold and silver[47] where he insisted that his results were correct. Among his several arguments, he mentioned that the members of the committee had found that cupellation of minium reduced by rosin, produced only one grain of silver and no gold. The committee had explained this result by saying that during the cupellation of minium reduced with black flux, the lead was subjected to a higher temperature, a fact that brought gathered together the gold particles randomly dispersed in its interior. To Sage, this was unbelievable.

Some of Sage's statements in this book[47] led to another collision with the research community. In the preface, he wrote that "he made known to the Minister of Finances some of his findings about assaying gold, but Mathieu Tillet (1714-1791), the Royal Inspector of Assays and Refining, tried to prove that they were invalid because of my claim that nitric acid dissolved gold." The Minister asked Sage to repeat his experiments in the presence, which he did and "proved that that the metal dissolved in aqua fortis". Hence, Tillet claimed that the metal was suspended and not dissolved in the acid. According to Sage *"the changes in weight of the gold button used increased with the amount and concentration of the nitric acid used. Each grain of gold lost about 1/32 of its weight in the presence of concentrated nitric acid"* [4]

Analysis of the white lead ore of Poulawen

In 1769, in letter addressed to de George-Louis Leclerc Buffon (1707-1788), Sage,[8] reported that he had examined the composition of the white lead ore found in Poulawen, Basse-Bretagne, and found that it was a compound of lead and

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[4] It is well known that aqua fortis (concentrated aqueous nitric acid) dissolves silver and other metals, but not gold. It is usually used to separate silver from gold.

marine acid (in this case, chlorine), containing 20 pounds of the acid per quintal (100 pounds). He further stated that the ore did not contain arsenic and should be considered white crystallized lead. Famous chemists that had previously examined the ore had declared that was mineralized by arsenic. It was known that the ore from Poulawen showed the presence of large white pearly prismatic crystals, which yielded 80 pounds of lead (plus a small amount of silver) per quintal. Sage calcined in a crucible a mixture pure of crystals taken from Poulawen with a flux, composed of potassium carbonate and charcoal and observed that when it started to melt it, swelled and effervesced and then continued to melt without additional phenomena. After cooling, the remaining crystals were analyzed and found to contain only marine acid and lead. Additional treatment with concentrated sulfuric acid resulted in the release of a gas having a penetrating smell, like that of marine acid, and left a highly powdered white residue. Sage believed that the mine was the result of the decomposition of a vitriol of Saturn (lead acetate), which is sometimes found in lead mines. In a later publication, Sage[48] repeated his claim that the white lead ore yielded about 20 pounds of marine acid per quintal, adding that calcinations of a similar white spathic iron ore lost 35 pounds of marine acid per quintal, and that crystallized calamine (zinc stone, Lapis zinci), contained 34 pounds of marine acid per quintal; that is, surprising amounts of chlorine, in spite that these minerals did not contain water of crystallization.

On December 5, 1772, Louis-Guillaume Laborie a Master apothecary of Paris, read a memoir to the *Académie* refuting Sage's results. Laborie's experiences showed that the ore was soluble in all acids; treatment of the ore with sulfuric acid yielded lead sulfate, with nitric acid yielded lead nitrate, and with vinegar acid (acetic acid), yielded the pertinent acetate, etc. etc. All these salts had exactly the same characteristics as those prepared by treating lead with the corresponding acid. Laborie results confirmed those of Sage that the mineral did not contain arsenic, but denied the presence of marine acid.

In order to solve the controversy, the *Académie* ordered a committee composed of Louis-Claude Bourdelin (1696-1777), Paul Jacques Malouin (1701-1778), Macquer, Cadet de Gassincourt, Lavoisier, and Baumé, to carry on the necessary experiments. The committee carried on a total of sixteen experiments, some of them very simple, such as tasting the ore and boiling it with water and tasting the solution. The rest of the experiments involved different chemical and metallurgical treatments. The final conclusion was that Sage had erred in his analyses, (the mineral did not contain marine acid) and that Laborie's results were correct.[49]

Potassium carbonate and hydroxide

In 1793, León de Pertuis de Laillevault (1757-1818) and Sage published a short book describing the procedures used for preparing potassium carbonate (salin) from the cinders of trees and plants as well as its transformation into potassium hydroxide.[50] According to the authors, salin was the solid matter removed by lixiviation and evaporation to dryness of the ashes of trees and plants; and potash was a more concentrated alkali prepared washing salin with water, followed by drying and calcination of the resulting solid.

The first chapter described the different procedures employed in Europe to prepare both materials and additional experimental evidence gathered by the authors. They burned a given weight (4000 pounds) of a variety of trees and plants (wheat, sunflower, vine shoots, boxwood, willow, elm, oak, poplar, etc.) and determined the amount of ashes and alkali produced from them. By far, the most productive were sunflower, wheat, and vine shoots; they yielded 80, 70, and 23 pounds, respectively. These results suggested that farmers could use the dry residue of these plants to obtain an additional income.[50]

The following sections described the best procedures for building and operating a factory for the manufacture of salin as well as the economics of the operation and the procedures for calcinating salin. A very detailed set of drawings was included.

The last two chapters described Pertuis's experiments to classify plants and trees, and their constituents, according to their ability to produce potash. Some of the results were: (a) bushes and their remains and plants produced three and five times more cinder, respectively, than the trunk of forest trees; (b) the amount of cinder obtained from trees decreased in the order trunk > branches > leaves, (c) plants burned at their maturity produced more cinders than those burned before or after maturity, (d) stinging nettle, gladiolus and flowering rushes yielded that largest amount of ashes per unit weight. Interesting enough, Sage's experiences indicated that raisin's marc yielded three times more salin than sunflower.[50]

Wine and derivatives

In 1800, Sage published a paper reporting a procedure to determine the amount of acid of sugar (oxalic acid) present in spirit of wine.[51] Already at the beginning he attacked the new chemical nomenclature in this words: *"The acid of sugar is known in the new nomenclature under the name of oxalic acid, but why not speak French? Why not leave it the name of acid of sugar since it is in this salt that this acid is most abundant, as sixteen parts of sugar produce ten parts of concrete acid. Rectified spirit of wine is called, but improperly, by the neologist chemists, alcohol. This term,* *says Trevoux, is derived from the Arabic word kol, which signifies to render subtle, to diminish, to reduce to an impalpable powder; it cannot therefore be applicable but to solid bodies. Philosophers must employ in their language more precision and correctness."*

Urban Hierne (1641-1724) had shown that heating spirit of wine with nitric acid decomposed it and deposited a salt after cooling. Afterwards, Scheele showed that this salt was of the same nature as the acid of sugar. Sage itself considered the spirit of wine as an acid soap since the ether and the oil of wine that composed it were miscible with water. The result of his experiments proved that the acid of sugar was the connecting bridge between the two components and was found in a large proportion. He heated a mixture of spirit of wine and nitric acid in a distilling apparatus and observed that the mixture decomposed with effervescence, accompanied with large bubbles and release of NO_2. The ether passed with an explosion into the receiver and perfumed the laboratory. The distillation was continued until about 3 % of the original volume remained. After cooling, the residue was found to contain beautiful crystals of acid of sugar, shaped as tetrahedral prisms, in slightly acid liquor. From 16 ounces of rectified spirit of wine Sage obtained one ounce, one dram, and 23 grains of solid acid of sugar (about 31.5 grams). When the acid was in combination with ether and essential oil of wine, it burned with them, since the combustion of spirit of wine left no residue.

In another manifestation in favor of the phlogiston theory, Sage stated that although heat was necessary for disengaging the inflammable spirit from wine, it nevertheless existed in it. He believed that there it was engaged by a portion of the tartar, which was found in the residuum of the distillation of the wine. Heat acted, in all probability, on a glutinous matter similar to that found in the sediments of wine; after it was separated and thickened, the spirit of wine was disengaged and volatilized.

The same experiment was repeated using concentrated sulfuric acid instead of nitric acid. Distillation caused resinification and charring of the spirit of wine and liberation of the ether. According to Sage, "this kind of essential oil, surcharged with inflammable matter, was unchanged by acids, and could be considered as inflammable gas in the form of a fluid, which indeed has all the properties".[51]

In a following paper, Sage discussed the fermentation of sugar to produce wine.[52] He indicated that this was an spontaneous process helped with the cooperation of an extractive matter or yeast. Yeast was the light lees, separated from beer that had been newly put into the cask. It was composed of glutinous and extractive matter, with a certain quantity of beer, and formed the most powerful kind o ferment.

Sage prepared a solution of sugar and pulverized tartar and observed that no fermentation took place, but the phenomenon took place when he introduced into the solution chopped vine leaves. He wrote that the addition of yeast to an aqueous sugar solution resulted in speedy fermentation, and recommended that to obtain a cheap wine it was convenient to use molasses. During vinification, the acid of the sugar changed its nature and assumed the character of an *acidum pingue*, which could be recognized in the two species of oil, composing the spirit of wine. To Sage, the spirit of wine was a kind of soap, formed of more than 1/15th part of the concrete (solid) acid of sugar, which incarcerated the odor of the ether and the essential oil of the wine, while at the same time, it rendered them soluble in water. Vinous spirit existed, ready formed, in wine where it was enveloped in tartar and an extract-refinous coloring matter, which, gave the wine by its, decomposition, a hard taste. In this state, it was called *absinthiated wine*.[52]

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