RESEÑA BIOGRAFICA

Antoine Baume.
Not only a hydrometer

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RESUMEN. Baumé fue uno de los famosos farmacéuticos de su época; fue un exitoso promotor que introdujo en Francia no solo la producción a gran escala de ácidos minerales, cloruro de amonio, drogas, y medicamentos, sino también, de equipos nuevos para esos propósitos. Estuvo muy activo en varios campos de la química, en particular, la química aplicada y la química industrial que estaban alborando. Fue un partidario de la teoría del flogisto hasta el final de su vida. Junto con sus actividades industriales, se dedicó también a la enseñanza de la química y la investigación en muchas áreas. Escribió varios libros sobre química y farmacia que fueron reproducidos muchas veces y también traducidos a otros idiomas. Se le recuerda, generalmente, por su hidrómetro, el primero en ser construido con escalas reproducibles.

ABSTRACT. Baumé was one of the most famous pharmacists of his time, he was a very successful champion that introduced in France not only the large scale production of mineral acids, ammonium chloride, drugs, and medications, but also new equipments for these purposes. He was very active in various fields of chemistry, particularly applied chemistry and industrial chemistry, which were just beginning to develop. He remained loyal to the phlogiston theory until the end of his life. Parallel to his industrial activities he devoted much time to chemistry teaching and research in many fields. He wrote books on chemistry and pharmacy that went through many editions and translations. He is usually remembered by his hydrometer, the first one to be built with reproducible scales.

INTRODUCTION

Chemists and chemical engineers are familiar with Baumé through the hydrometer that carries his name. They are generally unaware that he also contributed to other areas such as pharmacology, manufacture of ammonium chloride, bleaching of silk, analysis of saltpetre, etcetera. Here we describe his personal life and career, his fall from wealth to poverty during the French revolution, and his industrial and scientific achievements.

LIFE AND CAREER[1-6]

Antoine Baumé was born on February 26, 1728, at Senlis, some thirty miles of Paris, the son of Antoinette Courroye (1702-1752) and Guillaume Baumé (1683-1771). His mother was a descendant of an old Polish-Jewish family (the Polecqs) that had converted and had settled in Senlis, in the Saint-Rieul parish, around 1591. During the four generations the Polecqs had lived in the parish, many of them had occupied themselves as *pâtissiers-rôtisseurs*. In the beginning of the 1700's Antoinette's father owned and operated in Senlis the two popular inns Saint-Antoine and Grand-Cerf. Guillaume worked as *maître pâtisserie-rôtisseur* at the Saint-Antoine inn and eventually married Antoinette, who brought the inn as dowry. Antoine was the oldest of four children, Antoine (1728), Guillaume (1729), Hippolyte-Barthélémy (1730), and Louise (1733). He seems to have had the advantages of a fairly well to-do home, because the family business was very prosperous.

Nothing is known about Baumé's infancy or first education. It is only known that about 1743 he was appointed apprentice to a pharmacist in Compiègne on the Oise (where Joan de Arc was captured in 1430 and where in 1810 Napoleon first met Marie Louise of Austria). This first job may have been prompted by the fact that his father originated from Compiègne and also that he had lent to the nurse Sisters of a local convent premises adjoining the inn to install their pharmacy. Four years later (1745) Antoine moved to Paris and found a position with in Claude-Joseph Geoffroy's dispensary in rue Bourg-Tibourg, Paris, where under the influence of his growing ambitions as an auto-didact he began to develop his interest in theoretical chemistry as well as in pharmacy. Geoffroy was the son and grandson of Parisian apothicaries and the brother of Etienne-François Geoffroy (1672-1731), a very influential and famous chemist of that time, the first to publish, in 1718, a table of chemical affinities (*tables des rapports*). Geoffroy's tables remained unchallenged until 1773 when Baumé proposed drawing up two separate tables to represent relative affinities at low and high temperatures, respectively. His suggestion was carried into effect by the Swedish chemist Torbern Bergmanné.[2]

Baumé's employer was also a respected scientist; he was a member of the *Académie des Sciences* and a fellow of the Royal Society of London. Baumé served under Geoffroy for six years and eventually was put in charge of the laboratory.

During his stay with Geoffroy, Baumé became strongly interested in the phlogiston theories of Joachim Becher (1635-1682) and Georg Ernst Stahl (1660-1734) because they tried to give one interpretation to phenomena that seemed very different. Stahl had shown, for example, that the combustion of carbon or sulfur were transformations that obeyed the same mechanism that those experienced by lead or tin, when heated in air. Stahl had presented the problem (today known as oxidation) as the loss of the phlogiston contained in the carbon, sulfur, lead, or tin. The idea was interesting but the interpretation was somewhat adventurous.

In 1752 Baumé approached the Parisian guild of *mâitre apothicaires* and requested to be admitted as candidate. Initially his candidacy was rejected because he did not satisfy the conditions required to have the right to take the examinations (''*autant de lettres que les statuts et règlaments du corps le demandent*''). According to the guild regulations, the candidate had to have studied grammar, as well as four years of apprenticeship and six of internship, both in Paris. After the initial rejection, Baumé appealed to the Royal authorities, referring to a royal declaration issued at Versailles (April 26, 1692), and to the decree of the Royal Council (October 18, 1746), that allowed the *maîtres apothicaires* of Paris to accept into *maîtrise* a certain number of ''*marchands sans qualité*''. The last term included those candidates that had been admitted into the societies of arts and professions of Paris and other cities, without an apprenticeship, a master work, experience, research, or an examination that attested to their capacity, but only on the grounds of their being Roman Apostolic Catholics of proven morals and honesty.

The King ruled in Baumé's favor and as a result on January 28, 1752, he was allowed to matriculate as a candidate. After paying the required duties the apothicaire Pierre-Jacques Vassou was appointed to be his *conducteur* or leader, a person that was supposed to update the candidate in all the usages of the profession (nomenclature, terms), assist him in preparing his examinations, and to arrange all the visits he was supposed to make to the juries, the lieutenant general of the police, etcetera.

The entering examinations took place in three stages. The first one was called ''*lecture*'', and consisted of a three-hour exam by the syndics of the guild and nine other master apothicaires, selected by the syndics. The second exam was the ''*acte des herbes*'' and the third was an exposition of *chef-d'oeuvre* (master work), which Baumé took on October 7, 1752, after having presented to the jury seventeen items of his production that included syrup of chicory, snake powder, zinc flowers, distilled wine spirit, burnt lead, laudanum, orviétan, a dermal unguent, an antinephritic potion, Bellegarde, an expectorant, etc. (a picturesque comment is that the entry in a modern French dictionary for several of Baumé's preparations is ''quack medicine''!). On October 7, 1752, Baumé was accepted as *maître apothicare*.

At the age of twenty-four, Baumé found himself with a degree but without economical means. A question that remains unanswered is why he, the first-born son, did not approach his well-established family for help. Anyhow, he was fortunate enough to find support from Pierre-Joseph Macquer who offered to become his partner in the opening of a pharmacy, *leva boutique*, in the rue Saint-Denis, across the Church Saint-Lieu, in the populous quarter of *des Lombards*. Macquer was a member of the *Académie Royal de Sciences*, *docteur-regent de la Faculté de Médecine*, *pensionnaire de l'Académie des Sciences*, author of ''*Dictionnaire de Pharmacie*'', and as Baumé, a supporter of the phlogiston theory. Baumé devoted all his efforts to insure the success of the business, and in addition he studied Latin, installed a large chemical laboratory for doing experiments, and organized a course in chemistry that the two partners were intent in dictating.

According to the regulations stated in ''*État de médecine, chirurgie et pharmacie*'' of 1776, besides preparing drugs and selling them, Baumé was also allowed to issue price-lists, exactly the way pharmacies do it today. There still remains a copy of ''*Prix courants des préparations chimiques et pharmacie qui se trouvent à Paris chez M. Baumé, apothicaire*,'' a twenty-four page list (issued in 1775) and kept at the *Faculté de Pharmacie* in Paris. This list contained, as stated in its front page, more than two thousand articles corresponding to the vegetable and animal kingdoms (cantharids, white of whale, etc.), to galenic pharmacy (vegetable powders, Opodeldoch balm, esprits, tinctures, distilled water, etc.), and to veterinary pharmacy (like stinking balls for horses).

In 1762 Baumé transferred his facilities to larger premises located in rue Coquillère, in the Saint-Eustache parish. Here he pursued his business aggressively, publishing price lists of his various items and articles of promotional nature in the different daily papers. For example, the January 19, 1767, issue of the *Avant-Coureur*, carried a piece of his explaining the qualities of *acide marine*, or *esprit du sel* (hydrochloric acid) and informing the public that he had installed a facility for its large-scale fabrication, allowing him to sell it for half the previous price (30 sols per livre). Besides the pharmacy itself, the new premises had an auditorium and six well-provided laboratories where Baumé prepared and purified large quantities of diethyl ether, mineral acids, medicines, as well as distilled essential oils. Here Baumé occupied in retail sales and chemical and drug manufacture.

As a result of his manufacturing activities, Baumé was granted, in 1767, a permit for the large-scale manufacture of ammonium chloride in Gravelle, near Charenton. In this action he was following the steps of his mentor, Geoffroy, who had been the first to make sal ammoniac in France. This industry was supposed to substitute the ammonium chloride that at that time was totally imported from England and Egypt. The manufacturing process was based on the reaction of marine salt with ammonium carbonate obtained by the calcination of nitrogenous organic materials. The reaction was facilitated by the addition of calcium hydroxide. The chlorides of calcium and magnesium reacted with the ammonium carbonate, calcium sulfate precipitated and the solution was evaporated and crystallized to produce ammonium chloride impure. The salt was then purified by sublimation. Anyhow, this new venture did not last long because the partners disagreed with the modification of the manufacturing process that Baumé proposed. The closing of the facilities left France again dependent on the import of the salt.

When Jean Hellot (1685-1766) passed away his position in the *Académie des Sciences* became vacant and, contrary to Baumé's expectations, it was not offered to him but to Paul-Jacques Malouin (1701-1777). Baumé became so depressed that he, as he himself wrote naively in his book ''*Élements de Pharmacie*''[7] that he thought that he would have to give up forever the hope of receiving such an honor. Eventually, on December 25, 1772, Baumé was admitted to the *Académie des Sciences* in the rank of *adjoint-chimiste*, replacing Antoine Laurent de Lavoisier (1743-1794) who had been promoted from *associé-chimiste* to pensionnaire. A little afterwards he published his book "*Chimie Expérimentale et Raisonnée*." In 1778 the Académie promoted him to the rank of associé chimiste and then to pensionnaire in 1785. He retained this position until 1793 when the Académies were suppressed by the Convention. In 1796 Baumé became *associé non-resident* of the chemistry section of the *Institut National de France*.

In 1780 Baumé sold his pharmacy and production facilities to the two apothicaires François Dreux and François Fourcy Ganduin, in order to dedicate himself totally to research.

In 1781, at the age of fifty-three, Baumé married Marie-Louise Matis, a shop assistant, with whom he had a relationship for fourteen years, and in 1783 had with her a daughter, that eventually would marry Louis Margeron, a military pharmacist. Berton[1] raises the hypothesis that Baumé decided to marry because he did not want to be alone and without children at a later age. The marriage was dissolved after six years of never ending mutual complaints, apparently because of the different personalities between the partners. Marie-Louise retired to the convent of the *Dames de la Miséricorde*, and Baumé continued his business and scientific work. In 1787 he withdrew completely from outside activities and bought for himself in *Les Ternes* a country house.

The period of the French revolution found Baumé in the company of his only daughter, materially well established after having sold his business for a substantial amount of money. In 1785 he was promoted to *pensionnaire* of the Académie and in 1787 he accepted an invitation to become *démostrateur* of the Collège de Pharmacie, replacing Louis Alexandre Jacques Mitouart (1766-1848) who had passed away. This acceptance came after he had rejected in 1780 the position of *Prévôt-Directeur* of the same institution. By that time, Baumé's loyalty was split between the ideals of the Revolution and the Duc d'Orléans. Eventually he suffered the destiny of all those that lived from their rent, his property was confiscated and was left to survive on his small academic pension only. He was left absolutely destitute when on August 8, 1793, the Convention closed all the Académies.

In 1792 Baumé with other academicians such as Jeans-Charles Borda (1733-1799), Amédée-Barthelémy Berthollet (1780-1810), Antoine-François Fourcroy (1750-1809), Pierre-Simon Laplace (1749-1827), Joseph-Louis Lagrange (1736-1813), and Antoine Laurent de Lavoisier (1743-1794), were made members of the *Comité de Consultation des Arts et Métiers*, created by the National Assembly, and reconstituted by the Convention. Lavoisier was guillotined on May 8, 1794, after being accused of manipulating the quality of tobacco. Lavoisier was one of the General Farmers (*fermiers généraux*) that handled the tobacco monopoly. Stocks that had an excessive amount of water had to be destroyed. The charge was that excessive water increased the price of the material, as well as 'endagered the health of the consumer'. Among the general Farmers, Lavoisier was one those that had found some raw material that contained excessive water and had ordered its destruction. But the public opinion was excited; it was believed that the defective tobacco had been sold, with the corresponding potential health damage. For political reasons the King appointed an inquest commission, composed of Antoine Alexis François Cadet de Vaux (1743-1828) and Baumé. Cadet de Vaux and Baumé wrote a report exonerating Lavoisier and approving the destruction of new tobacco stocks that were too wet. Cadet Vaux and Baumé tried to save Lavoisier from the death penalty, but failed. As a consequence, Baumé resigned his membership in the Comité, claiming that his age and the fact that he was living outside Paris made it impossible for him to fulfill properly his duties.

After the end of the Terror period, Baumé appealed to the *Comité d'Instruction Publique du Directoire*, requesting economical assistance, stating that he was 68 years old and that all the economical means he had, had been acquired by hard work, and that his contribution to chemistry had led to his appointment to the Académie. His means had been taken away and his present fortune was inadequate for supporting himself and his 12-year old daughter. He included his *curriculum vitae* and requested that restitution of the Académie pension that he had before. The committee ruled in his favor and awarded Baumé the sum of 1 500 livres.

With this sum Baumé returned to public life, republished several of his books, and in 1796 he opened a new pharmacy, across the cemetery of Saint-Jean, with his future son-in law, Louis Margueron. This new venture was very prosperous, and eventually led him to transfer the premises to rue Saint-Honoré, which he would keep until his death in 1804.

Davy[3] indicates that different sources disagree completely on the date and place of Baumé's death. Anyhow, from his analysis of the information he comes to the conclusion that Baumé died on October 15, 1804, in Saint-Honoré, at the age of 76 years.

The first subject that interested Baumé was sulfuric ether or vitriolic ether, that the pharmacists called anesthetic ether, and the chemists' diethyl oxide. He presented his results to the *Académie Royale des Sciences*, in the form of a 300-page essay, that was published in the journal *Mémoires des Savants Étrangers* in 1760 (this journal was dedicated to publish the works of scientists that were not members of the Académie).

In 1777, Baumé won first prize for an essay on the best furnaces, stills, and other apparatuses to be used in the distillation of wine.

As Bett says[3]: ''The history of Baumé is one of triumph over missing education, and over traditional superstitions. He was a restless worker and innate experimental ability and versatility. He wrote on an infinite number of widely different subjects such as the bleaching silk and dyeing fabrics, the cement industry, and methods of fire prevention. With Macquer he stimulated the manufacture of porcelain in France, to replace Chinese imports. His ample knowledge is reflected on the one hundred and twenty-eight contributions to the famous *Description des Arts et Métiers*."

Baumé was a passionate for his profession and in addition to his many practical activities he found the time enter into polemic with other colleagues, and reply under various funny pseudonyms (Antoine Rabé, Mme. de Blanc-Noir; Guillaume le Résolu, *le Distillateur de l'Art de Chemie*, etc.), to their writings. For example, the Gazette de Médicine, carried in 1762 two contributions, "*Lettre de Jérôme Brule-Fer, garçon maréchal, a l'Occasion d'un Probléme sur le Souffre*" (October 13, 1762), and *Réponses aux Réflexions d M. Bellanger, sur l'Extrait, par une Longue Digestion. Par M. Antimone Vabe, étudiant en Pharmacie*" (October 2, 1762). In the latter, the author indicates that the previous year he took the course *Élements de Pharmacie*, dictated at Baumé's premises. His works are true treasures of information for the study of the science of medicine prescriptions of his time and the iatrochemistry (which studied chemistry as a means of treating disease) of which he was almost the only practitioner.

As Deyeaux says[4]: Baumé entered the history of science when pharmacy and chemistry were starting to shed off the principles of ignorance, the theories of the alchemists, and to base itself in experience. Stahl's theories, based on the existence of phlogiston and the four elements air, water, fire and earth, were wrong, but they constituted a working hypothesis that had evolved with Lavoisier and the scientists of the end of the eighteenth century to today's atomic theory. Baumé was located in the transition from Stahl's school and Lavoisier's school. Without economic means and titles, but being full of merits, working capacity, and manual ability, and having a Cartesian spirit, he positioned himself at a very young age at the front line of the scientists of his time.[3]

Baumé did not dedicate all his time to teaching and business, he continued his work and experimentation on different subjects. As a result he published in 1757 a *Mémoire sur le Refroidissement que les Liqueurs Produisent en s'Évaporant* (Cooling effect produced by the evaporation of liquids), in 1758 Analyse *d'Une Eau Minérale Singulière qui se Trove à Douai en Flandre* (Analysis of a peculiar mineral water found in Douai en Randre); in 1760, *Observations sur la Cristallisation des Sels Neutre qui ont pour Base un Alkali Fixe ou un Terre Absorbante* (Observations about the crystallization of neutral salts that have as base a fixed alkali or an absorbent earth), and *Décomposition du Tartre Vitriolique par l'Acide Nitreux Seul* (Decomposition of sulfate potassium by the action of nitric acid alone). All these works appeared in the journal *Mémoires des Savants Étrangers*.

Baumé played an important role in the history of pharmacy by helping overthrow some of its traditional superstitions in the shape of complicated formulas and nauseating ingredients. He wrote several books that went through many editions and were translated to many languages. The first one, *Elemens de Pharmacie*[7], was published in 1762. Its cover page indicated that he book contained all the fundamental operations of the art, their definition, and their explanation based on the principles of chemistry. It also included the proper selection method, preparation, and mixing of medicaments, as well as the procedures to recognize their falsification. Other chapters described the prescription of medicines in use, the art of confectionery, and the preparation of table liqueurs. It also contained a table of the virtues and doses of medicaments. The book should be considered a pharmacopoeia in which Baumé tried to eliminate the empiricism of ancient pharmacy, as well as to introduce as much as science as possible.[2] His bitter drops (Baumé's tincture) remained in the French Pharmacopoeia until 1949, under the name "Teinture de fèves de Saint-Ignace composée". They were employed against flatulent colics.

His second book, *Manuel de la Chimie*,[8] was published in 1763. In the preface Baumé stated that this book should no be considered a treatise on chemistry, it was simply a detailed exposition of the experiments that were performed during the course given by him and Macquer, and it should be of particular interest to any who wanted to install of chemistry laboratory.

The third book, *Chymie Experimentale et Raisonné*, was published in 1773, in three volumes.[9] Together with the *Manuel de Chimie*, they are Baumé's most important contributions and represent a summary of chemical knowledge at that time. It not only described all the operations that were performed in chemistry, but it also added a large number of other developed by Baumé.

It is also appropriate to mention that Baumé was one the main contributors to the *Dictionnarire des Arts et Métiers.*[10] Among others, he wrote the entries about alum, pharmacy, manufacturing practices, pyrotechnics, tinning, degreasing, confectionery, distillation, lime burning, perfumery, casting, the art of manufacturing lead, porcelain, saltpetre, ammonium chloride, and vinegar.

SCIENTIFIC ACTIVITIES

We will now present some of Baumé's most relevant contributions the teaching of chemistry and pharmacy, to pharmacology, industrial chemistry, and instrumentation, but before doing so, we will discuss the phlogiston theory that so much affected Baumé's life and ideas.

1. Phlogisto[11]

Experimental chemistry of the eighteenth century was dominated by the discoveries about gases; a new branch was emerging that studied the formation of gases, their properties, and in particular, the chemistry and properties of air. Unfortunately, the new findings were hard to integrate into the general theories in vogue at the time. To do so chemists were developing certain ingenious but unsatisfactory theories, based on the attraction among small particles of matter and the existence of an element having many properties: the phlogiston. By 1770 all chemists were Newtonians and phlogisticiens.

The phlogiston theory, proposed first by Becher and extended by Stahl, assumed the existence of an elementary principle, the phlogiston or element of fire that carried the property of combustibility. It existed in all combustible bodies and was released when the latter burned in the presence of air. In addition, when a 'metallic earth' (oxide) was reduced by carbon or sulfur, that had large amounts of phlogiston, they transferred it to the oxides, which then became metals. In other words, the phlogiston was considered like antioxygen. Stahl admitted that for a metal to burn in air (also its oxide) it had to lose something, that made it to burn, and that his disciples called phlogiston. After combustion their remained a *terre*, or a *chaux* (calx), that was believed to be a simple body. It was then possible to write:

Metal (or combustible)→ calx + phlogiston

Stahl supposed that the phlogiston released by combustion became part of the atmosphere, hence air had a large concentration of this element. The large interest in the theory structured over this hypothetical element was due to the fact that for the first time in history, the same hypothesis led to a coherent and simultaneous interpretation of two very important phenomena: oxidation and reduction. Stahl's theories were widely adopted among chemists in the 18th century such as Henry Cavendish (1731-1810), Joseph Black (1728-1799), Joseph Priestley (1733-1804), Carl Wilhelm Scheele (1742-1786), Amédée-Barthélemy Berthollet (1748-1822), Louis-Bernard Guyton de Morveau (1737-1816), and Macquer.

Anyhow, experimental evidence was continuing to accumulate that contradicted the phlogiston theory. On one side, the increase in weight that occurred in the calcination process where bodies were losing phlogiston, and on the other, the role of air in the calcination and combustion processes. Eventually, the discoveries of Lavoisier, published in 1774[12] led to the demise of the phlogiston theory.

Baumé was a firm adherent of the theory, although he did not do work to validate it; he remained faithful to it until the very end of his life, even after Lavoisier's discoveries. The decomposition of water, one of the first significant achievements of the chemistry of the new school, was scorned by Baumé who saw it ''as a brilliant experience that illusions scientists and makes them arrive at the wrong consequences.'' The recent progress in the manipulation of gases, the discovery of oxygen, and the evidence on oxidation reactions continued to leave Baumé skeptic. He declared, for example, ''I will believe in the recomposition of water when you will perform your experiments without employing water in your equipment.''

He wrote: ''Fire is a matter essentially fluid, it is the principle of fluidity in bodies and it is always in movement. Phlogiston is the principle of odors, colors, and the opacity of bodies. Phlogiston becomes fixed when it becomes part of the composition of the *terres*, and the contrary, it is very volatile when it is the elementary fire that predominates over the earth principle. Fire is really heavy when it is combined in bodies, it is also very heavy when it is free but in this last case it is impossible to appreciate its weight because it does not touch the bodies that it penetrates, and it has always an excessive movement. Phlogiston is a composed matter, formed by the direct union of fire and a very simple, but yet unknown substance.''

In his famous book ''*Chimie Experimentale et Raisonnée*''[9] Baumé distinguished between eight different forces in chemical compounds.

Baumé's refusal to discard the phlogiston theory and accept the new theories of chemistry cost him dearly: The *Institut National des Sciences et Arts* systematically refused his request to be promoted from *associé-non residant to titulaire*.

2. Sulfuric ether (diethyl ether)

Baumé's first scientific publication[13] was related to the preparation of the ether and examination of its combination with other substances. The raw materials, wine spirit and vitriolic acid, were mixed in equal amount, heated, and the distillate recovered until until SO_2 started to be released. At this point the remaining substance looked like bitumen and was nonvolatile. The distillate was distilled again and separated into a light and a heavy phase. The heavy liquid phase contained materials that could not be identified. The solid bituminous phase was found to contain iron, Prussian blue, and arsenic, which probably were part of the impurities present in the raw materials. In the discussion of his results Baumé indicated that the vitriolic acid was very avid for water and transformed the wine spirit into an oil that was insoluble in water. Also, that vitriolic acid was absorbed by the remaining solid residue. He also added that he was completely sure that the blue color observed was the iron derivative of Prussian blue.

Baumé's procedure should be considered a good example of the knowledge level of chemistry in general, and organic chemistry in particular, at his time. What was then called sulfuric ether was simple the result of the etherification of ethanol.

Baumé's procedure was shortly thereafter, modified by Louis-Claude Cadet de Gassicourt (1731-1799). He let the still cool before the decomposition of sulfuric acid had begun, and then introduced a fresh amount of esprit of wine. The savings in sulfuric acid allowed Cadet to reduce Baumé's price from twelve livres to forty sols per ounce (there were 20 sols per livre).

3. Areometer

Réaumur had already introduced a hydrometer that was graduated in an arbitrary manner. It was built after the pattern of the so-called *baryllion*. Such a graduation depended on the instrument and disappeared with it, there was no relation between the readings of one hydrometer and another. The situation was similar to the one that existed with thermometers before Réaumur introduced his instrument.

The merit of the hydrometer, which Baumé introduced in 1768, was the presence of a scale based two fixed points that could be reproduced very easily. The introduction of such a ''universal'' scale, allowed obtaining the same reading with different pieces of instrument.

As Baumé himself wrote, the new densimeter had the advantage that it was constructed on the basis of two fixed points that could be duplicated very easily. One of them was distilled water and the second a aqueous solution of salt, of known composition. The location of the degrees was not arbitrary, Baumé marked his degrees by dividing the distance between the two fixed points by the number of livres of salts used to prepare the calibrating solution. Baumé constructed two areometers, one for liquids heavier than water (acids, salt solutions, etc.) and another for liquids lighter than water, like esprit of wine. The scale of the first areometer had 15 identical degrees that started from the density of pure water (0 degrees) and ended with that of the density of an aqueous solution containing 15 % wt. salt (15 degrees). In the areometer for light fluids the scale was divided into 10 units, the lower one corresponding again to pure water, and the last one to the density of an aqueous solution containing 10% wt. of salt. But in this case the zero was not the lower end of the scale, it was extended beyond by 50 equal parts (degrees). From the constructive details of his areometer, it is clear that Baumé was assuming that the density of aqueous solutions of salts varied linearly with their concentration. Baumé realized that this linearity was not true aqueous solutions of alcohol, but apparently he did not realize the volume contraction that took place.[5]

Baumé's areometer appeared in the French Pharmacopoeia until

1884, afterwards it was replaced by densimeters graduated directly in density. Perry's handbook still carries a table for the conversion of degrees Baumé to specific gravity[14] and Kirk-Othmer's Encyclopedia of Chemical Technology[15] carries a table for the density of sulfuric acid in degrees Baumé.

According to Crosland[16] ''hydrometers of increasing sophistication were used to determine the alcoholic content of wines, beer, and spirits. In 1768 Lavoisier carried out a study of the use of hydrometers (*aréomètres*) to determine quickly and accurately the specific gravities of liquids and recommended this method for finding the specific gravity of alcoholic liquids. Several hydrometers were in use for excise purposes under the ancient regime in the different provinces of France, one of the best known being that of Baumé. By the early nineteenth century the hydrometer was generally accepted both in France and England as the best method for determining alcoholic content in dutiable liquids, but legislation required that a specific type of hydrometer or alcoholmeter be employed. In 1816 the French authorities specified Cartier's instrument, which was substantially the same as that of Baumé.''

4. Saltpetre (potassium nitrate)

In eighteenth-century France domestic provision of salpetre was the monopoly of a guild, the *Salpêtries du roi*, to whom the crown had granted exploitation rights when the weapons based on gunpowder began to be employed in the fifteenth century. In France from the XIVth century onwards, the manufacture and sale of gunpowder came under State monopoly and was administered by the gunpowder and saltpeter authority. In 1664 the royal monopoly was delegated to a "Gunpowder Farm." The Farm was a group of private entrepreneurs who operated the arsenals for their own profit in return for providing the state with agreed amounts of gunpowder and controlling the supply of saltpetre.[17]

In 1774 Anne-Robert-Jacques Turgot (1727-1781), comptroller general of finance under Louis XVI (1754-1793), the last King of France, instituted a crash program to develop the saltpeter industry and engaged the help of the *Académie des Sciences* to achieve its objectives. He replaced the Gunpowder Farmer by a new administration, ''*Régie royale des poudres et saltpêtres*'' (Royal Gunpowder and Saltpeter Company). The saltpetermen were paid a fixed price for their crude product, regardless of its quality. There were no reliable means for estimating the percentage of saltpeter in the yellow lumps, although different subjective tests were used for this purpose.

In 1790 the Ministry of Finances requested from the *Académie des Sciences* to set up a commission to discuss the procedures by which the titer of saltpetre was determined. The committee was headed by Berthollet and included Jean D'Arcet (1725-1801), Baumé, and Fourcroy. In 1791 they issued their report in which they indicated that raw salpetre contained four substances, potassium nitrate (nitre), marine salt, calcium nitrate, and small amounts of magnesium chloride and nitrate. Since the potassium substance was the only component useful for the manufacture of gunpowder, they suggested that the price be fixed only on the basis of its content. The committee suggested that the methods proposed by *des Estrées*, the powder commissioner in Tours, be adopted after making the necessary tests and establishing the pertinent calibration tables. Basically, the procedure was based on the observation that when water was saturated with potassium nitrate salt, it did not dissolve more of the same, as long as the temperature was kept constant. Nevertheless, care should be taken of the fact that it could dissolve a salt of a different nature affecting the original solubility of potassium nitrate. For example, dissolution of the marine salt contained in the raw material *increased* the solubility of potassium nitrate. The régisseurs had prepared a table of corrections to take into account these changes in solubility, that the committee had verified, and thus they recommended that this method should be the one to be used.

Baumé did not sign the report and later it became clear that he had done so because he was had developed another method of analysis, which he published some months after the issuing of the *Académie* report. On March 24, 1792, Baumé read to the *Académie* a report in which he proposed that the titer of saltpetre be determined using the fact that cold water dissolved preferentially sodium chloride. Three cold washes, followed by crystallization, were enough to give a good indication of the amount of potassium nitrate present.

Baumé's procedure for the purification of saltpetre was used during the revolutionary period.

5. Attraction and repulsion during crystallization of salts

This work of Baumé, published in the paper Avant-Coureur of November 16, 1772, gave some observations that today look very funny, about the forces that operate during crystallization. First, Baumé recalled that Newton had demonstrated that bodies exerted attraction forces one on another and that he also believed that natural bodies had the property of repelling one another. Newton believed that that both forces behaved like algebraic numbers do, that is, repulsive forces started from where attractive forces ceased to exist. Baumé went to on to claim that the existence of attractive and repulsive forces could be easily demonstrated during the crystallization of salts. According to him, if next to one of the faces of a vessel containing a saturated solution of Glauber salt (sodium sulfate) was put a bottle full with the same salt, then crystallization would take place on only in the face in question. On the other hand, if instead of Glauber salt the bottle contained *sel de tartre* (potassium carbonate), a repulsion would take place and crystallization would take place in the opposite face. Baumé indicated that he had repeated the experience with many other salts and found the same results, although he was still unable to find the relation among the. Not only that, he claimed that the effect was also present when the two vessels were not in direct contact.

Baumé's conclusions were contested by Lavoisier who read a report to the Académie proving that the supposed anomalies observed by Baumé' were not due to Newton's laws but to the different cooling rate of the vessel's walls.

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