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Highlights of Spanish chemistry at the time of the chemical revolution of the 18th century

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Summary. A number of outstanding Spanish chemists and some of their major chemical contributions in the 18th century are briefly considered indicating that Spanish chemistry got a very high level at the end of the century, departing practically from nothing at the beginning of the century. The Vergara School played a very important role as the first national institution for chemistry despite of the fact that it decayed in a few years for a number of reasons. The discovery of three new elements is briefly dealt with (Pt, W, V) and the adoption of the new modern French chemistry in Spain as well as a number of critics against some of Lavoisier's theories and nomenclature posed by some Spanish chemists are considered.

Introduction

A lot of attention has been paid by Spanish authors to evaluate the real dimensions of the Spanish contribution to the experimental sciences [1–7]. Traditionally, the experimental sciences have not been the subject of much attention as derived from a number of factors, in spite of the fact that the role of Spain has been very important in medieval times as a link between Arabic science and western Europe. Special mention deserves in this respect the Ripoll Monastery (end of the 10th century) in Catalonia and the School of Translators of Toledo (12th century), the contribution of which was of a very great value for the scholastic period.

Isolated famous personalities such as Ramon Llull and Arnau of Villanova appeared in the 13–14th centuries, while in the 14th century – in contrast to what was the case compared with Paris and Oxford – practically no scientific contributions to science appeared in Spain.

In the 16th century the great historical crisis derived from the religious reformation influenced very badly the development of Spanish science as a result of the official censorship and scientific isolation imposed by the policy of king Philip II (for instance, botany studies were still based almost exclusively on Plinius and Theophrastus teachings).

In the 17th century the censorship became somewhat softened and industrialisation began to take place in Asturias (north of Spain). However no real scientific climate existed and the "Index" of forbidden books played a role in the decay of botany studies. Chemistry was solely in the hands of physicians, pharmacists and swindlers up to the end of the century where the situation began to change and a few interesting personalities appeared (Alfonso Limón Montero, Juan de Cabriada, Félix Palacios y Baya, etc.).

At the beginning of the 18th century it can be said that neither alchemists nor chemists existed. The physicians were not interested in chemistry as derived from the scarce impact of iatrochemistry in Spain and galenic teaching and practice was the rule. Rather than helping chemistry it can be stated that medicine was rather against chemistry. As a matter of fact, up to the first half of the 18th century no chemistry teaching was taught at any Spanish University or School until a number of scientific academies were created in Madrid and in some provinces. The extended evil was that – in contrast to many European countries – the experimental sciences were not taken into account in the Spanish universities even mathematics to a very little extent. They were mainly stagnated around aristotelic and scholastic teaching.

In the first decades of the 18th century, however, some official backing to science started under Philip V and Ferdinand VI, which led to the foundation of the Museum of Natural History in Madrid. A marked trend was to open and to engage foreign scientists at this time to teach the experimental sciences, to direct factories and mining enterprises and to work in them. As a result it may be said that the massive engagement of foreigners was excessively expensive and brought little productivity. The main problem in the country continued to be the lack of interest and motivation towards the practical sciences.

Such a situation was also the case, though with not such a prominence, in many European countries. Even in the French Encyclopedia little room was given to chemistry as derived from its essential empirical character at that time, under the inconvenient influence of the phlogiston theories so that G. N. Venel, main redactor of the chemical words of the French Encyclopedia, was little optimistic about chemistry and expressed his desire to arrive at the day where some dexterous, enthusiastic and dared chemist would bring about a real revolution of this science to put it to the level reached by other sciences. Some 34 years thereafter such a premonitory desire would be made reality by Lavoisier.

Fortunately, later on, under the auspices of King Charles III, in the last third of the 18th century the overall picture began to change for the best leading to a very important flourishing of the Spanish science in mineralogy, mining, metallurgy, botany, mathematics, astronomy and chemistry, as derived from the foundation of a number of new institutions (observatories, botanical gardens, laboratories, academies, chirurgical colleges, etc.) created to improve the pitiful situation of science in the Spanish universities. As a matter of fact, chemistry began a new period free from the ties of adjacent sciences (pharmacy, botany, etc.).

However, to a great extent the new scientific picture created in Spain in the last part of the century is to be credited rather to a number of outstanding personalities than to the general official scientific policy despite of the indiscutable fact that the new scientific policy put the basis to a new concept and development of science in Spain in this and the coming centuries.

The precariousness of the factual results obtained through the important official effort carried out are to be ascribed mainly to the following factors:

Excessive foreign engagement with little success, despite of the fact that names such as Bowles, De la Planche, Proust and Chavaneau, among others, spent many years working in Spanish institutions and laboratories;

– Final failure of the official laboratories established in Vergara, Segovia, Valencia and Madrid;

– Excess of bureaucracy and administrative action;

– Inconsistencies in the effort of continuity as derived from the despotic royal support;

– Lack of interest and motivation for the learning of chemistry among most of the pupils driven more by curiosity than by real vocational attitude.

However, a small élite of Spanish chemists were able to achieve important results which led to the discovery of three new chemical elements (Pt, W, and V), interesting investigations in the measurements of the quantitative composition of the air, investigations in a number of fields of inorganic chemistry, important improvements in mining and metallurgy, etc. Such achievements derived in part from the chemical training acquired by their protagonists in other countries (France, Germany and Sweden, especially) as well as from the growing impact of the quickly developing modern chemistry in France which led to the chemical revolution, based essentially on the explanation of the process of combustion, the setting of a new systematic and rational nomenclature of chemistry, the establishment of quantitative analytical procedures, development of the chemistry of gases and the growing interest for practical and industrial chemistry.

La Sociedad Vascongada de los Amigos del País [8]

In the realm of chemistry special interest deserves the foundation, by King Charles III, of the Sociedad Vascongada de Amigos del País in 1764, which was the first of the Economic and Scientific Societies founded in Spain, based on the interest in experimental sciences, industry and commerce. This society served as a pattern for other societies which were emerging in a few years.

This society used to publish the very well-known "Extractos de las Juntas Generales" which can be considered as the first scientific journal published in Spain, including original notes and memories, although many chapters of the "Extractos" cannot be considered to be of scientific character, many of them being even of scarce or no originality. In 1780 a section appeared in this publication dedicated exclusively to chemistry, which was inaugurated by Proust.

Special mention deserves R. M. de Munibe y Areyzaga, who travelled over whole Europe under the auspices of the "Sociedad Vascongada", studying chemistry in Paris with Rouelle (teacher of Lavoisier) and in Uppsala with Engreston (pupil of Cronstedt). He was the first Spanish chemist to attend in 1772 the courses of the School of Mines of Freiberg (founded 1766) and was probably the first to introduce the blowpipe technique in Spain, which he learned in Sweden. Munibe was a very promissing, competent and motivated chemist, very active during his very short life, since unfortunately he died in 1774 at the age of 23.

In 1777 the foundation of the Real Seminario Patriótico (Vergara School) took place which means a new stage for the "Sociedad Vascongada" and, in general, for the Spanish chemistry of the time, since Proust and Chavaneau were engaged as professors and investigators and the Elhuyar brothers carried out most of their work which led finally to the isolation and discovery of tungsten. Much important work was done as well at the "Escuela de Vergara" on platinum chemistry, which allowed Chavaneau finally to find out a method to obtain maleable platinum and to elaborate a good separation procedure.

The discovery of three new elements: Pt, W, V

Interestingly enough the Spanish chemistry of the 18th century departing from a non-existent status at the beginning of the century has achieved in the century a comparable level with most European countries, not in quantitative terms but as regards to the high quality of scientific modern chemistry reached by a few individuals. Among them deserve special mention: Munibe (1751–74), Ibañez (1749–1809), J. J. Elhuyar (1754–96), F. Elhuyar (1755–1833), Ulloa (1716–95), del Rio (1765–1849), Marti y Franques (1750–1832), Arejula (1755–1830) and Porcel y Aguirre.

Probably the most brilliant contribution of Spanish chemistry of this time refers to the discovery of the three new elements Pt, W and V, the history of which is bound to interesting, even anecdotical facts.

Platinum [9, 10]

Although it appears native in nature, this metal was unknown in ancient times, being first described by the Spanish marine Ulloa in 1735 following its discovery in the alluvial banks of the Pinto river in Colombia (Popayán Bishopric) although the first extensive description of the metal appeared in the book "Relación histórica del viaje a la América Meridional" published jointly by Ulloa and Jorge Juan in 1748. The metal was given the despective name "platina" (inferior silver) as derived from its difficult manipulation. The metal was known already by the American indians, but not in Europe. Much work was carried out in the Vergara School on platinum, especially by Chavenau and later on in Mexiko by F. Elhuyar, which led to the establishment of a sort of Spanish platinum monopoly during a few years at the end of the 18th century, within what has been called the "Platinum Age in Spain".

Tungsten [11–16]

Shortly after Proust's departure from the Vergara School to Segovia and Madrid, F. de Elhuyar enters into the Vergara School where together with his brother J. Manuel he carried out important chemical work beginning to publish in the "Extractos" in a transparent and finished chemical style. The Elhuyar brothers were pupils of the Swedish chemist Bergmann, attended the Freiberg Mining School and continued investigations on the "scheelite" ore (calcium tungstate) initiated by Scheele.

Both brothers are equally responsible to have finally obtained the new metal which they called "wolfram" as isolated from a tin mineral brought from Zinnwalde (Saxe-Bohemia) in 1783 after final reduction of tungstic acid by charcoal. The metal was given the name "tungstene" in France, following the Swedish etimology ("heavy stone" = tungsten), although the German chemists adopted Elhuyar's name. The slight weight of the scarce Spanish scientific literature could not influence much on the adoption of the final name for the element.

After their Vergara years the Elhuyar brothers played a most important role in the teaching and development of mining and metallurgy in Mexico, as praised very eloquently by Humboldt, where F. Elhuyar founded the Real Seminario de Minería, designed after the model of Freiberg Mining School. F. Elhuyar cared a lot for the economic industrial obtention of platinum and was the discoverer of chloro-argentic acid, among other achievements in chemistry.

Vanadium [16, 17]

This element was first controversially discovered by J. M. del Rio in 1801 and isolated from a vanadinite ore from Zimapán (Mexico) being given the names of "eritronium" and "panchromium" by his author, as derived from the varying beautiful color changes of its solutions. Del Rio attended the Freiberg Mining School with an official grant where he met Humboldt and afterwards was in Paris with Lavoisier. Later on he was in charge of the Escuela de Minería in Mexico founded by F. Elhuyar, where he published the first book on mineralogy to appear in America entitled "Elementos of Orictognosia". Del Rio has the priority in the discovery of the new element, named later on vanadium by Berzelius as related to the scandinavian goddess "Vanadis" following the rediscovery of the element by his pupil Sefstrøm. This is a sad case of confluence of a number of unhappy facts. Humboldt took from America a memory of del Rio on the new element which went lost in a shipwreck [9] carrying a sample of the mineral called "brown lead of Zimapán" which he submitted to the French chemist Collet-Descotils for analysis, who thought it to be an ore of the recently discovered element chromium (1797). Unfortunately, del Rio admitted the error and the element was the object of a rediscovery in 1830 by Sefstrøm which was admitted smartly by his master Berzelius. Later on Wöhler recognized vanadium to be the "eritronium" element earlier discovered by Del Rio and this fact gave rise to a cooling of the friendship between Del Rio and Humboldt, who played an important role – willingly or unwillingly – in the matter in question. Vanadium has been the first chemical element isolated in a laboratory of the New Continent, about a century before the second one niobium ("columbium") could be isolated.

Other contributions

Special attention deserves the autodidact Marti y Franques (1750 – 1832), who first studied at the Cervera University which he abandoned discouraged by the scholastic style of its teaching. He carried out quantitative volumetric measurements on the air composition which are described in his "Memorias sobre los varios métodos de medir la cantidad de aire vital de la atmósfera", where he states that "100 parts of air contain 79 parts of mofeta (nitrogen) and 21 parts of "vital air" without reaching the value of 22". This was the most exact air analysis of the time, including the analysis carried out by Lavoisier. Most interesting, he established the invariability of the air composition. Although Marti y Franques was a good friend of Lavoisier he did not hesitate to recognize Cavendish's priority over Lavoisier on the synthesis of water.

In the industrial sector A. R. Ibañez (1749 – 1809), who deserves special nomination, created the first modern iron foundry in Spain in 1797 in Sargadelos (Lugo), where the first iron blast furnace was erected using charcoal. Political uproar related to the after-war consequences of the Napoleonic occupation of Spain led unfortunately to his early execution, blamed as "afrancesado" by the absolutist Government of Ferdinand VII.

Acceptance and critics to Lavoisier's theories in Spain

As a rule, the French chemical revolution, brought about mainly by Lavoisier was established very quickly and easily in Spain as derived mainly from the coincidence of the development of chemistry in Spain with the period of the French revolution as well as from the close connection of the Spanish chemists with their French colleagues, in spite of the fact that phlogistic views were generally held by the Spanish chemists who had been mainly educated in northern countries as was the case of the Elhuyar's brothers.

However, it is very interesting to discuss briefly the views and counterproposals of a few Spanish chemists, who disagreed with some of Lavoisier's theories.

As stated before, in the very backward country which was Spain at that time in general, modern chemistry and the new French system of nomenclature was taught just one year after its publication in France, in the Vergara School, not in Madrid, at a time where even the most advanced scientific countries were very loath to accept it. The main protagonists of this fact were a chemist, T. A. de Porcel y Aguirre, and a mathematician, J. de Mas, who was forced to learn and explain chemistry in Vergara after the absence of Chavaneau [8].

Very interesting are as well the objections posed by J. M. Arejula (1755 – 1830) [18] who was a surgeon of the Spanish Navy and was pensioned to study chemistry in Paris with Fourcroy, being one of the most appreciated pupils of his master and being charged by him with the tasks of chemical demonstrations. Arejula spent a few years in Cádiz, at the Colegio de Cirujanos de la Armada, founded in 1748 by the king Ferdinand VI, where he built a very good chemical laboratory. He is the author of a book entitled "Reflexiones sobre la nueva nomenclatura química", published in Madrid in 1788, where he adheres completely to the new principles of the methodology of the new nomenclature, but strongly criticises the word *oxygen* and the theory of acidity of Lavoisier, which he considers to derive from an insufficient and faulty generalization or inductive process.

As for his claim against the word oxygen, Arejula means that the root "oxis" is ambiguous and contradictory since it applies as well to the acid oxides of the non-metals as to the metallic oxides, lacking any acid property at all. Therefore, the word oxygen is a contradictory word. To avoid such situation he proposed a new word for oxygen, namely *Arkekayon*, or *arxicayo* (Spanish derivation from the former Greek term) from the greek words "arke" (= principle) and "kayo" (= to burn), considering *arxicayo* as "burning principle", since the most typical property of oxygen, most general and most reasonable to consider, is its capability to burn, to bring about any type of combustion. Arejula considers the reduction process to be a double reaction of antagonistic characteristics since the most powerful reductor, carbon, is burned in a reaction of this type while the oxide, or any substance bound to oxygen is "deburned". Therefore, for Arejula a reduction reaction is the sum of a combustion and a "decombustion" reaction [18].

Additionally, Arejula proposed to substitute the French word *azote* (elementary nitrogen), and *gas azotique* (gaseous nitrogen) by the words *ázoe* and *gas ázoe*, respectively. Such denominations were backed by Fourcroy ("Eléments d'histoire naturelle et de Chimie", 3^e edition, 1789) and were finally accepted by the European scientific community. Finally, Arejula proposed, as well, to replace the French word *tungstene* by *wolfram*, to respect the name proposed by its discoverers in 1783 (Elhuyar brothers).

Arejula's critics against Lavoisier's acidity theory, on the other hand, are based on the rebuttal of its four main principles, which he considered as chemical axioma unsufficiently supported by enough experimental evidence:

1) "All acids contain oxygen";

2) "Any body which undergoes chemical combination with the oxygen portion, which is capable to receive, becomes an acid"

3) "Acidity and the acid properties of a compound are the greater as its oxygen proportion increases"

4) "The body able to receive more oxygen will become the most terrible acid".

Arejula was right on these claims against Lavoisier's acidity theory (existence of hydracids, lack of acid proporties in water, etc.) but it was not until 1810 that Lavoisier's acid theory was dismantled by Davy's electrochemical isolation of chlorine, formerly called "muriatic oxigenated acid" from hydrochloric acid, one of the strongest mineral acids which was demonstrated to lack any oxygen.

Chavaneau opposed as well Lavoisier's denomination of oxygen ("Elementos de Ciencias Naturales", Madrid, 1790) proposing to change its name to *pirógeno* (from the greek "piros" = fire and "Genos" = generator) considering – as Arejula did – that the most characteristic property of oxygen is not to generate acids, but fire, being indispensable to effect the combustion process.

Finally, we will return to T. A. Porcel y Aguirre, the only outstanding pupil educated in the Vergara School. Although he did not make any important discovery he was a real modern and competent chemist. Educated in Paris he was a typical Spanish representative of the French antiphlogistic school (in contrast to the Elhuyar brothers, educated in Sweden and Germany). He was probably the first Spanish chemist who first wrote his agreement with the new chemical nomenclature proposed by Fourcroy, Berthollet, Couve de Mourveau and Lavoisier.

Notwithstanding, Porcel was, as well, a detractor of Lavoisier's acidity theory, based on similar critics to those already dealt with in connection with Arejula. On the same grounds, Porcel proposed the oxygen name to be changed to *comburente* (the chemical element) and *gas comburente* (gaseous oxygen) as well as proposed to change the names of the metallic oxides ("calx") to *combustos metálicos*, since the word "comburente" relates to the most constant property of oxyen and the term "combustos metálicos" indicates not only chemical composition but as well the way they have been obtained [19].

As concerning Lavoisier's "azote" denomination, Porcel considered this name to be essentially inspecific, since not only nitrogen in the air but other different gases behave as "inert" or as "mefitic", depending on the type of experiment, so that confusion results from such facts and the denomination in question. Therefore, Porcel proposed the denominations of *nitrígeno* (generator of nitric acid), or *amoniágeno* (generator of ammonia) for nitrogen, denominations which he thought congruent with what had been done in connection with the denomination of "hydrogen" (generator of water).

Conclusions

The names and facts related to the Spanish chemistry and chemists of the 18th century, especially the last third, show quite clearly that a profound change took place in Spain concerning the interest for chemistry, a real new science which received its official backing at the time of the French chemical revolution in 1789. It is very remarkable that chemistry in Spain arose from practically nothing in this century to became an important subject which allowed a small élite of Spanish chemists to participate in the discovery of new chemical elements, to carry out investigations of interest in the chemistry of the moment and, finally to criticise – based on sound reasons – important chemical theories and to propose more reasonable names with regard to the new systematic rational chemical nomenclature. We can certainly conclude that – among other achievements – the illustration period meant a gigantic step for the development of modern chemistry in Spain.

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