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CONSTRUCTING THE CENTRE FROM THE PERIPHERY

Spanish Travellers to France at the time of the Chemical Revolution

1. INTRODUCTION

During recent decades, scientific activity in the Spanish Enlightenment has attracted the attention of many historians of science. The policies of enlightened governments have been regarded as an important step in the process of modernisation of eighteenth-century Spanish society. At the beginning of that century, a new Bourbon dynasty was established in Spain and its policies have been regarded – mainly by conservative historians – as an attempt to introduce "foreign" ideas and practices into Spain. These policies have also been considered as a major effort to "modernise" a supposedly traditionalist country isolated from the rest of Europe and under the control of the powerful Catholic Church. Due to this caricatured image, enlightened Spanish governments have been very appealing for a group of politicians and historians who actively participated in the recent so-called "Spanish transition" from dictatorship to democracy, as they considered themselves engaged in a process of modernisation very similar to that initiated by their eighteenth-century forerunners. This trend reached its apex during the commemorations of the bicentennial of Carlos III, the most outstanding representative of Spanish enlightened despotism. One of the most important parts of the so-called modernisation process, then and now, was science. According to this view, the isolated Spain scarcely participated in the Scientific Revolution of the sixteenth and seventeenth centuries and enlightened governments tried to solve this problem by implementing three main policies: (a) Reforming the recalcitrant universities, which were anchored in old scholastic ways of teaching, or, to avoid opposition, founding new scientific establishments in which new science could be taught and cultivated; (b) Appointing foreign scientists in some of the new institutions, so that they could introduce new ideas into Spain and train disciples; (c) Sending young students – *pensionados* [1]– abroad in order to

Ana Simoes, Ana Carneiro, Maria Paula Diogo (eds.), Travels of Learning. A Geography of Science in Europe, *Kluwer Academic Publishers, 2003, pp.* 143-188.

improve their scientific background in the most famous European academic centres. Scientific trips are therefore considered a key part of Spanish enlightened policies and are mentioned in almost every study concerning eighteenth-century Spanish science[2].

Taking into account the history of chemistry, this image of the Spanish Enlightenment fits perfectly the nineteenth-century narratives of "chemist-historians" who regarded the late eighteenth-century as the period in which chemistry emerged as a scientific discipline. This "revolution-foundation" of chemistry took place almost at the same time as the arrival of the *pensionados* in Paris, the most prominent centre of chemistry, where Antoine Lavoisier was developing and propounding his theories on chemical combustion[3]. In this context, the quick and painless reception of the new chemistry in Spain has been related to the *pensionados*' trips, and historians have been interested in finding out when and where Spanish travellers met the famous French chemists who created the new ideas. The diffusionist image has been reinforced by the supposed lack of a substantial chemical tradition before these trips took place. According to this thesis, there were no powerful supporters of phlogiston theory in Spain as there were, for instance, in Germany or Britain, so that Spanish *pensionados* could easily introduce new ideas without major resistance. As a result, little attention has been paid to issues such as the reasons and interests that attracted historical actors to chemistry, the processes of appropriation of new teaching and research practices, or the context of reception in which new ideas and practices were accommodated[4].

The abandonment of the diffusionist approach and the new images of the chemical revolution offer a renovated historiographical framework through which the *pensionados*' trips should be analysed. New historical studies have portrayed eighteenth-century chemistry as a consolidated discipline in several European countries, including investigative programmes and well-established theoretical concepts, experimental practices and instruments[5]. The image of a revolution-foundation has been abandoned and new historical actors and geographical contexts have entered the picture. Although many different approaches coexisted, the chemical revolution is no longer regarded as an achievement of a small group of British and French chemists but as a larger and more complex process involving other European countries and scenarios. The image of diffusion from a creative centre to a passive periphery can hardly be supported after studies such as those focusing on new chemical nomenclature which have been portrayed as the final outcome of a process of negotiation among a large network of European chemists[6].

In tune with this approach, the context of reception has gained importance in studies on the chemical revolution. Increasing attention has been paid to issues such as the structure of national chemical communities and the different professional groups who were interested in chemistry and their reaction against (or for) new ideas[7]. The vehicles and mechanism that materially supported the exchange of ideas and practices inside the European network of chemists have also been a topic of study. As in other areas of historical research, the non-verbal process of learning has been regarded as an important vehicle of transmission of new ideas for late eighteenth-century-chemistry, an experimental science which involved emerging and undefined concepts as well as practical work in the laboratory; a type of knowledge and practice mainly transmitted by listening to and talking to other chemists or seeing and manipulating in the laboratory, rather than through scientific texts. These personal contacts transmitted not only scientific concepts and practices but also institutional models and values about science. Due to this range of historical problems, scientific trips have gained space in historians' research agendas. Studies on scientific trips during the chemical revolution have been focused on exchanges between Britain and France, particularly those related to the transmission of pneumatic chemistry from Britain to the Continent[8]. There are also studies on individual travellers who played a significant role in the transmission of the new chemistry to a particular national context[9].

Unfortunately, studies about other travellers are few in number and limited almost entirely to departure and arrival dates and personal contacts. In some cases, the scant number of relevant sources available transforms historical inquiry into a troublesome and time-consuming activity. In consonance with some recent works[10], our study has adopted a quantitative and comparative approach, aiming to identify general trends as well as significant and representative singular cases to be studied in detail. In order to increase the number of historical actors under study and the information available on them, we have used a variety of archival sources related to both their scientific and technical activity as students, teachers, researchers or even spies, and their status as foreigners and exiles. The data base supporting our study contains information about eighty biographies of Spanish people who for a variety of reasons travelled around Europe between 1770 and 1830 and who were involved in different activities related to chemistry, ranging from attendance at chemistry courses, publication of memoirs, papers or books on chemistry, or some chemical subject, to a professional career in chemistry.[11]

The first outcome has been a preliminary periodisation which is based on the changing characteristics of departure and arrival contexts related to the

trips, the purposes and aims of travellers and their sponsor institutions, and their activities before, during and after travelling abroad. This periodisation will be discussed in the first section of this paper. In the second part, we analyse the institutions that supported these trips, their reasons for and interests in acting in this way and the arguments chemists employed to obtain their financial support. Finally, the third part focuses on the spaces of sociability and networks in which the travellers were temporally integrated during their travels as well as the strategies that they followed to appropriate the theoretical and practical knowledge they were seeking.

2. ROUTES AND PERIODS OF SPANISH SCIENTIFIC TRAVELS FOR THE STUDY OF CHEMISTRY.

France was the country most frequently visited by Spanish scientific travellers, particularly those interested in areas such as chemistry, for which France became a major scientific centre during the eighteenth-century. Apart from sharing a long common border, Spain and France enhanced their political and cultural relationships during the Enlightenment thanks to the common Bourbon dynasty which ruled both countries after the Spanish War of Succession. Paris, where the most important French scientific institutions were situated, was the most frequently visited city, although the University of Montpellier also attracted many Catalan medical students during the eighteenth-century thanks to the particular relationship between the two geographical areas. The other important group of travellers related to chemistry was formed by students who attended lectures on mining and metallurgy at the Central European schools of Freibergand Schemnitz. Some of them visited other countries with relevant mining activities, such as Sweden. Britain was an important destination for those interested in areas such as medicine, nautical science, astronomy, optics and scientific instrumentation techniques, and became a major refuge for liberal exiles during the first third of the nineteenth-century. Trips to other countries were related more to particular circumstances than to general trends. For instance, by the middle of the eighteenth-century the Italian peninsula became a haven for Jesuit scientists expelled by Carlos III's government.

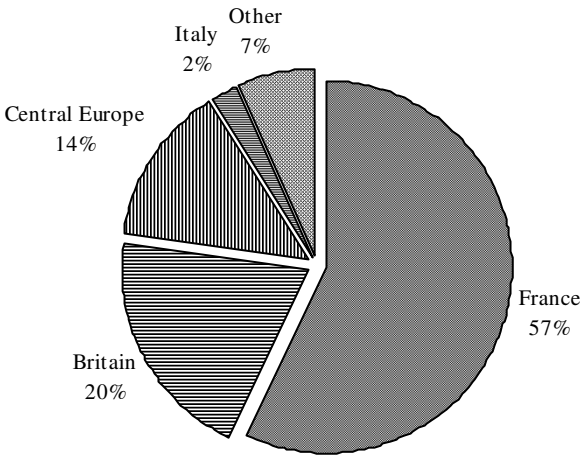

Figure 1. Destinations of Spanish scientific travellers, 1770-1833[12].

During the period studied, substantial changes occurred not only in the goals of the institutions promoting the trips, but also in the main features of the European institutions frequented by Spanish travellers and in the scenario that travellers had to face back in Spain. Taking into account these changing features, three main periods can be distinguished. Although many other earlier scientific trips might be mentioned, the first period actually started in 1770 when the first substantial group of travellers arrived in Paris, around the "crucial year" in which Lavoisier developed an investigative programme which led him to abandon former theories on combustion and to adopt the quantitative chemical method with which he is generally associated[13]. The first *pensionados*, however, hardly knew anything about Lavoisier's research because the first important public exposition of his emerging ideas was not published until 1777. Moreover, these first travellers were probably more interested in topics related to mining and metallurgy than in theoretical and methodological problems of chemistry. Most of them were members of the Basque Economic Society (*Sociedad Bascongada de Amigos del País*), the first and most famous of a large group of similar societies that appeared all over Spain during the 1780s and 1790s, aiming to influence Spanish agriculture and industry. The number of trips reach its peak during the late 1780s thanks to the royal support of Carlos III's enlightened government and some institutions related to medicine and surgery such as the School of Surgery of Cádiz. As a result, a large number of Spanish *pensionados* were able to attend chemistry lectures and meet chemists such as Antoine Fourcroy, who, at that time, was committed to a campaign in defence of the new chemistry using various media such as

textbooks, journals, lectures, dramatic experiments made at prestigious scientific institutions and private meetings in salons such as Mme. Lavoisier's[14].

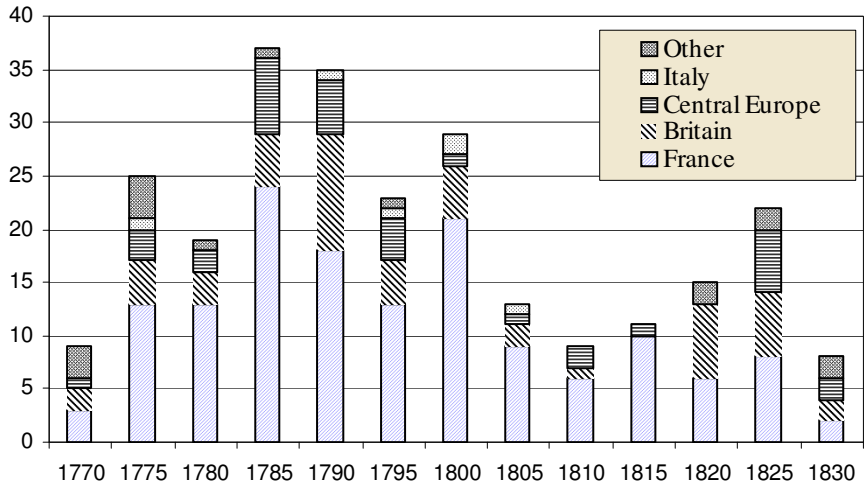

Figure 2. Spanish Scientific Travels, 1780-1833

Scientific travels were seriously affected by the Spanish government's panic-stricken reaction to the French Revolution. The Count of Floridablanca, the enlightened Minister whom Carlos III imposed on his son Carlos IV, reinforced control at French-Spanish borders, banned revolutionary propaganda and implemented book censorship and control – even the *Journal de Physique* was banned by a Royal Order in 1791. In 1790, Floridablanca forbade Spaniards to be educated in a foreign country and, finally, trips were completely suspended during the Spanish war against the French Republic in 1793[15]. Spanish residents in Paris were requested to return to Spain and those who decided to remain in France, such as the engineer José María Lanz (1762-1837), were punished and removed from their posts[16].

The second period began at the end of the war in 1796. After several important setbacks of involving Spanish arms against French troops, Manuel Godoy, the most influential person in Carlos IV's court, changed sides and joined the French against Britain. As a minor consequence, but important in our narrative, trips to France were again reinstated, although the number of trips did was not substantial until the first years of the nineteenth-century. The Peninsular War (1808-1814) created an extremely adverse context for

scientific trips. Although the government of Napoleon's brother, José I, attempted to maintain enlightened policies and support the trips of *pensionados* in France, war expenses exhausted royal resources and prevented the development of many of the *afrancesados*' projects[17].

The third and last period of our study starts in 1814, after the defeat of the Napoleonic army and the return of Fernando VII, who created an absolutist government and persecuted liberals and *afrancesados*, including many important scientists. Domingo García Fernández, Josep Garriga i Buach and Francisco Angulo spent several years in France. Another important flux of Spanish exiles to France and, mainly, to Britain happened in 1823. After several unsuccessful uprisings, Spanish liberals staged a successful revolution in 1820 and forced Fernando VII to reinstate the Constitution of 1812. The European Coalition of Absolutist countries, the so-called Holy Alliance, became alarmed, and France undertook a military intervention in Spain with the aim of restoring Fernando VII to absolute power. The Spanish absolutist King, backed by French arms, revoked the constitution in 1823, and the ruthless repression that followed forced many liberal scientists to spend part of their lives in exile. Many of them, such as Juan Manuel de Aréjula and Andrés Alcón Calduch, were old *pensionados*[18].

The social and political changes associated with the crisis of the Old Regime strongly shaped the scenario in which scientific trips took place. The first important group of travellers arrived in Paris in the 1770s. Supported by the enlightened atmosphere of Carlos III's years, they found a favourable context on their return to Spain. Thanks to this situation, most of them were appointed to scientific and teaching institutions, so that they could teach or develop the knowledge they had acquired in France. The crisis of the Spanish Enlightenment made the completion of the whole process more difficult. The *pensionados* of the second period, who travelled at the beginning of the nineteenth-century, found in France a more sophisticated group of scientific and teaching institutions related to chemistry but, in contrast, when they returned to their country, their careers were interrupted by the military and political crisis which agitated Spanish society during the first third of the nineteenth-century. Some of them were politically persecuted for their collaboration with the *afrancesados* or liberal governments and, in some cases, they were compelled to leave the country, constituting thus the third group of travellers identified in our study. This third group included mostly exiles or the sons of exiles, and even though some institutions, such as the Museum of Natural History, sponsored scientific trips, most of these displace persons were not officially part of scientific projects or policies. As a result, they hardly contributed at all to reviving Spanish scientific activity.

3. REASONS AND INTERESTS

The trips of the *pensionados* involved significant human and material effort, mainly for the institutions who supported them and for the individuals who made them. The government and the industrial or teaching institutions had to obtain financial and political support, arrange housing and subsistence, gain access to foreign training centres and foster the development of institutions that could integrate the travellers after their trip abroad. Which institutions or political powers supported them and what did they expect to attain with these trips? As their biographies show, the *pensionados* were required to make a considerable personal effort, which included not only learning new languages and dealing with new customs and manners but also accepting the risks associated with travelling along unsafe routes and the troubles related to wars or social and political disorders, which were quite common in European countries during the late eighteenth and early nineteenth centuries. They also embarked on uncertain and problematic academic careers, which did not secure them a permanent position that would enable them to develop their scientific research or even to earn a living. In this context, one might wonder why the principal actors of such trips regarded such investments and efforts as justified.

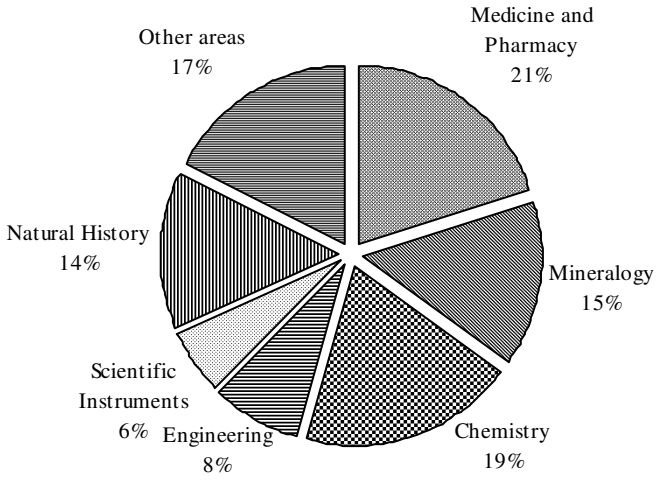

Figure 3. Trips and disciplines, 1770-1830.

To answer these questions we must analyse the rhetoric that connected the complex network of interests - not always explicit neither public - motivating these trips and the main reasons that supporters invoked. In the case of chemistry, academic lectures and inaugural speeches frequently

included a defence of the usefulness of this discipline, which had gained manpower, political support and institutional acceptance in Spain by the end of the eighteenth-century. However, before becoming an institutionalised science, several topics related to chemistry were studied and taught in different venues, including pharmaceutical workshops, medical faculties or metallurgical and mining centres. Hence, during the first two periods under study, the trips were largely supported by groups or institutions related to these academic or technological traditions.

3.1 The practice of chemistry in eighteenth-century Spain and the promotion of scientific trips.

The first group of institutions that supported chemical travellers were related to medicine, surgery and pharmacy, chemistry being a traditional auxiliary topic in the scientific background of these occupations and professions. A second support network was formed by the mineralogical and metallurgical centres that sponsored the first chemical travels at the beginning of the 1770s. In close relationship to this second network, a third group of trips was supported by civil or governmental institutions aiming to improve industry and agriculture by diffusing knowledge of what was later called "chemistry applied to the arts and manufactures". There were also some travellers who came from military institutions, mainly related to artillery. Each group had particular aims related to chemistry, and, as a consequence, different interests and expectations about the missions and activities of the travellers they supported.

3.1.1 Medical uses of chemistry

The old debate about medical applications of chemistry was revived during late eighteenth and early nineteenth centuries. Pneumatic chemistry, modern analytical methods and new explanations of combustion and respiration raised great expectations for medical applications of chemistry, transforming the relationships between the two disciplines. This situation was attractive for many Spanish chemistry students with medical or pharmaceutical degrees, one of the main groups of Spanish travellers to Paris during the late eighteenth-century. Many of them got in touch with one of the most outstanding supporters of medical chemistry, Antoine Fourcroy (1755-1809).

Juan Manuel de Aréjula (1755-1830), who was given a grant by the School of Surgery of Cádiz to train as a naval surgeon, was one of these. Attracted by the new chemistry, during his stay in Paris in the 1780s, he contacted Antoine Fourcroy and attended his lectures. When Aréjula returned to Spain, he was appointed professor of chemistry in Cádiz. In his

opening address, focused on medical applications of chemistry, he endorsed chemistry as a useful tool for the advancement of medicine. Like other authors, he discussed in separate paragraphs the applications of chemistry to anatomy, physiology, hygiene, pathology, *materia medica* and pharmacy. As an example of the uses of chemistry in medicine, he discussed his ideas on intermittent fevers and their cure, based on chemistry. In other parts of his talk, he emphasised the advantages of elemental analysis and the new theory of respiration as well as other achievements of eighteenth-century chemistry such as the theory of affinities, which he considered of great importance for the preparation and administration of medical drugs. He was very optimistic about medical uses of chemistry and did not consider any limitations in this area, not even for physiology and pathology, whose relation to chemistry was, in those years, a controversial topic. In this sense, Aréjula is a good example of the group of physicians and surgeons who saw the changes related to the "chemical revolution" as a great hope for the advancement of the theory and practice of medicine.

This confidence in the medical applications of chemistry was, in many cases, related more to the great popularity achieved by the new chemistry than to its actual success in solving medical problems. At the end of the eighteenth-century, many authors cautioned caution against the excessive use of chemistry in medicine; among them was Antoine Fourcroy, the author of numerous works on medical chemistry, including a scientific journal in this field. However, he criticised various hasty applications of chemistry to medicine, arguing that wrong uses of chemistry in this area could be very dangerous. In one of his papers, Fourcroy described the strong reactions his lectures elicited at the Medical Faculty of Paris:

> Young people enthusiastically follow my course on animal chemistry at the school of medicine. Their desire to learn is extraordinary; I am aware that the twenty lessons I impart on this very new area in chemistry give a great impulse to this branch of nature studies, but I control it as much as I can; I do not want to accelerate it, for fear of breaking that beautiful machine in my hands[19].

Aréjula, who attended Fourcroy's chemistry lectures, was perhaps among these exalted students. Other *pensionados*, like Francesc Carbonell i Bravo (1761-1837), adopted more moderate positions. After studying at the Montpellier Faculty of Medicine, where he attended Chaptal's chemistry courses, Carbonell wrote a doctoral dissertation on the uses and abuses of chemistry in medicine, in which he defended the difference between 'inorganic' and 'organic' bodies both in reactions studied in the chemistry laboratory, and those taking place inside the human body under the influence of the vital force. A large part of his dissertation focused on a critical

discussion of Baumès' nosological ideas and their therapeutic consequences[20]. Carbonell argued that all chemical nosology was 'defective' (*improvida*) and all chemical therapeutics were 'vicious' (*vitiosa*), but he praised chemical applications to hygiene (analysis of air, water or food, for instance) and *materia medica*, the part of the art of healing where chemical applications were more fruitful. As far as physiology was concerned, Carbonell thought that chemistry as well as physics and mechanics– should focus on studying the 'perfection of the instruments' (substances) which participated in life functions but not on explaining the causes of these processes that were developed under the influence of vital forces. Finally, Carbonell concluded that 'valid applications of chemistry to medicine' were very useful but their abuse could be pernicious[21].

One of Carbonell's most talented pupils in Barcelona was Mateu Orfila i Rotger (1787-1853), who pursued a brilliant career in Paris during the 1810s. He published several papers on medical chemistry and became the most famous toxicologist of the first half of the nineteenth-century in France. He was also the author of one of the most often reprinted textbooks on medical chemistry, in which he briefly discussed the uses of chemistry in medicine. According to Orfila, it was difficult to deny the utility of chemistry in determining the characteristics of drugs or in medico-legal research concerning cases of poisoning. He admitted however that other applications were the subject of debate among physicians:

> But what are the dangers of an excessive application of this science to medicine? Medical-chemists [médecins-chimistes], it will be argued, paying no attention to vital forces, only see in the exercise of the various functions of animal organisation, phenomena analogous to those observed in their laboratories; they heedlessly compare the properties of inanimate bodies with those of living bodies and establish theories in physiology which are purely chemical and false, and which are overturned by the slightest observation"[22]

Orfila argued that these criticisms had to be directed only to 'inattentive and little-enlightened observers' and not to 'savants' who 'incessantly interrogate nature' through 'experiments and observations' and who prefer 'new and well-established facts' to 'premature and unfounded explanations'. According to Orfila, such research would lead to 'the future perfection of physiology'. In agreement with his teachers Fourcroy and Carbonell, Orfila was not against chemical research in physiology but he did not agree with hurried and careless conclusions. However, recognising the existence of the controversy, Orfila wrote in the introduction to his book that he only offered medical applications of chemistry whose benefits were not contested, such as those related to therapeutics and legal medicine. Regarding 'physiological applications', he declared that his book included only the results of chemical experiments related

to physiology because this part of science was not advanced enough to be 'reduced to general principles'[23].

The three authors just mentioned are representative of different opinions and practices in the realm of medical chemistry. In spite of their divergence, their views offer enough evidence about the interest in chemistry shown by Spanish physicians, surgeons and pharmacists. This is the context in which training trips to Paris were promoted by institutions related to the art of healing, such as the Cádiz School of Surgery[24]. In contrast, Spanish medical faculties did not support any training trips, so the travelling expenses of physicians were usually financed privately. One example is Ignacio María Ruiz de Luzuriaga (1763-1822), a physician linked to the Basque Society, who travelled to several places in France and Britain during the 1780s. He attended Pierre-Joseph Macquer's (1718-1784) and Fourcroy's chemistry lectures as well as lessons on other medicine-related topics at the Parisian Medical Faculty, the School of Surgery and the Collège du Roi[25]. In 1784, he published a memoir in the French journal *Observations sur la physique* on "the decomposition of atmospheric air by lead". This paper is another example of the miscellaneous chemical topics that attracted the attention of Spanish physicians. Luzuriaga was interested in lead's properties because of the so-called "colique des Peintres" (painter's colic), a disease related to lead materials. In his paper, he recognised that he had not achieved any conclusive result on the matter. However, he confessed that this research had led him to a more interesting field: the new developments in pneumatic chemistry. He performed several chemical experiments in order to study how several bodies – among them, lead – "deprive air of its phlogiston"[26]. After remaining for several years in Paris, he travelled to Britain and attended William Cullen's lectures (1710-1790), obtaining an M.D. degree from the University of Edinburgh[27]. Eventually, Luzuriaga obtained royal support, and stayed in Madrid for several years after his return from Britain[28].

The most important group of Spanish physicians who travelled to France in the eighteenth-century went to Montpellier Medical Faculty rather than to Paris. The trips were encouraged by the strong cultural and economic relations between Languedoc and the Catalan area. Moreover, the council of Girona supported the "College of Girona", an institution founded in the Middle Ages which supported young students who wanted to study medicine in Montpellier. Some medical students, such as Josep Garriga i Buach and Francesc Carbonell i Bravo, attended Chaptal's chemistry lectures and, under his influence, were introduced to chemistry applied to the arts. Many of the *pensionados* of the late eighteenth and early nineteenth-century who came from a medical background were interested in this area and some of them, like Carbonell and Garriga, published papers or books on both medical and industrial chemistry[29].

3.1.2 Chemistry applied to the arts

During the eighteenth-century, chemistry underwent important changes in academic status and its relationship to other disciplines. Paradoxically, its consolidation as an academic discipline could not easily accommodate its old association with technological activities. The medieval opposition between *scientia* and *ars* implied a serious conflict for chemistry: if such a dichotomy was accepted, then for chemistry to be considered a science and to be accepted in learning societies, a substantial practical part of chemistry related to craft and industry had to be removed, namely all areas related to activities such as mining, metallurgy, dyeing, glassware, etc. By the middle of the eighteenth-century, the Swedish chemist Johann Gottschalk Wallerius developed a new approach which avoided the problematic dichotomy of *scientia* vs. *ars* and brought into existence the modern division of pure and applied chemistry. As Cristoph Meinel has pointed out, the new distinction fitted comfortably into the enlightened conception of science and its potential for useful applications[30].

This utilitarian image of chemistry was very attractive for Spanish enlightened governments, which aimed at developing agriculture and industry. This rhetoric was also in consonance with the main goals of the so-called *Sociedades Económicas de Amigos del País*, associations of enlightened clergy, wealthy aristocrats and businessmen who also struggled to improve industry and agriculture by supplementing the education of craftsmen with public courses, including chemistry lessons[31]. As a result, chemistry became a central area in the educational activities of these groups. Due to the scarcity of experienced chemists in Spain, the *Sociedades Económicas* were compelled to hire foreign – mainly French – professors to support training trips to other countries, – also mainly to France. The most famous Society was established in Bergara, in the Basque region, an area which had an important ferrous metallurgical industry. Thanks to the support of the Naval Ministry, interested in new foundry techniques, the Basque Society established a chair of chemistry in 1777 and appointed two young French chemists for this post: first Louis Proust (1754-1826) and then François Chabaneau (1754-1842). At the same time, the Basque Society supported several trips by its members and its members' young sons. Most of them travelled to Paris, where they followed a propaedeutic scientific instruction course preceding the studies and missions they were expected to accomplish in Central Europe in mining academies and mining sites or in the Swedish steel industries[32].

Like the Basque Society, other *Sociedades Económicas de Amigos del País* attempted to offer chemistry lectures, although only a small group succeeded in doing so. During the late 1780s, the Society of Valencia asked

the government to found a chair of chemistry applied to the arts. The chair was finally established in the Faculty of Medicine and lectures included applications of chemistry to the arts, industry and mining[33]. The *Sociedad Económica Aragonesa*, which was established in Zaragoza, also succeeded in presenting public chemistry lectures at the end of the eighteenth-century. The chair was closed during the Peninsular War, but reopened later on and remained active until the 1840s. Some former Spanish travellers to Paris occupied this chemistry chair[34]. Other Societies, such as those established in Granada, Oviedo, Santander, Seville and Valladolid, supported similar projects but were quite unsuccessful.

Another important professorship was established in Barcelona at the beginning of the nineteenth-century. This chair, supported by the *Junta de Comerç* (Trade Board), was founded in 1805 and occupied by Carbonell, a chemist who had studied in Montpellier and who wrote and translated several texts, including Chaptal's books, about chemistry applied to the arts and medicine. The *Junta de Comerç* supported several young students' trips to Paris, among them Orfila's. He was sent to Madrid in 1807 in order to study under Louis Proust's tutelage but, when he reached Madrid, Proust had returned to Paris, so Orfila decided to follow him and travelled to the French capital. There, he registered at the Medical Faculty and started attending public chemistry lectures, getting in close touch with Nicolas Vauquelin (1763-1829), who supported him during the difficult period of the Peninsular War, when Orfila was arrested by the French police and Vauquelin managed to get him out of prison. Although the Spanish government offered him an important post in Madrid, Orfila never returned to Spain and embarked on a meteoric academic career, becoming dean of the Paris Medical Faculty between 1831 and 1848[35].

The *Junta de Comerç* also supported other students' travels, and when the activity of other Societies decreased during the first third of the nineteenth-century, it became perhaps the most outstanding institution promoting these trips. The group of students related to the *Junta de Comerç* included Carlos Ardit (1777-1821), who was commissioned to report on dyeing technology in several parts of France and Switzerland. Orfila guided him during his stay in Paris, accepting him in his private chemistry lectures and introducing him to the staff of a large calico-printing factory in Jouy, near Paris, run by Christophe-Phillipe Oberkampf (1738-1815)[36]. Another student of the professorship of Chemistry was Esteban Desprats (b. 1788), who studied in the Paris Medical Faculty[37] and attended Thenard's chemistry lectures at the *Collège de France* between 1816 and 1820[38]. Josep Roura (1787-1860), Carbonell's successor in the chemistry chair of Barcelona, also spent several brief periods studying in Paris during the late 1820s[39].

Trips related to chemistry applied to the arts were also supported by the enlightened Spanish Government. As mentioned above, the Naval Office collaborated with the Basque Society by supporting Elhuyar's travels, aiming to modernise military cannon technology. Other *pensionados* were funded by the government to gather information related to artillery. Tomás de Morla (1752-1820), who wrote a famous treatise on artillery, travelled to several European countries with the captain of artillery José Guillelm. In 1788, they posted the Government several plans of industrial machinery and José Guillelm was requested to spend several months in the Netherlands to study the gunpowder industry[40]. The government also funded several trips to Central European mining academies and commissioned these *pensionados* to obtain information about mining and metallurgic technology. For instance, in 1791, three Spanish *pensionados*, who were attending lessons at the Freiberg School of Mines, were requested by the Government to visit mines and describe "every machine that might be interesting, especially the furnaces and lead foundry techniques [...] from Carinthia" (now in Austria). They were also to travel to Hungary and visit its mines and foundries, collecting information about procedures and industrial costs and products. The instructions specified that they were to write a structured report of their observations when back in Freiberg, at the same time as they attended the courses at the School of Mines. After the courses had finished, they were requested to travel again around the Saxony and Bohemian regions and "thoroughly scrutinise their mines and foundries, mainly those of copper and tin"[41].

The Spanish government supported other trips related to industry and some of these travellers became very influential chemists. Among them was Domingo García Fernández (1759-1826), who later translated Berthollet's *Élémens de l'Art de la Teinture*. When García Fernandez received governmental support, he had already visited Paris on a private trip, and attended lectures at the School of Pharmacy[42] and the Medical Faculty[43]. In 1783, he was commissioned to study chemistry applied to the arts in Paris and to observe and report on the dyestuff procedures and technology of the famous *Manufacture des Gobelins*[44]. Some years later, he was appointed professor of a chair of chemistry applied to the arts in Madrid and was again sent to Paris with the mission of improving his background in this field and buying the necessary scientific instruments for the new professorship[45]. The Spanish Government also asked García Fernández to observe and report on several French industries:

> … to learn the recent progress in chemistry, to purchase instruments that cannot be made here [in Spain], and, above all, to gain detailed knowledge about what is performed at the Mint Houses of Paris and Bordeaux regarding smelting, refining, extracting techniques, methods of assaying and recasting our coins, trying to acquire Plans, or Models of

> the most useful Furnaces and Machines, and extensive knowledge about the mechanism of works, expenses, prescribed precautions aiming to decrease waste and lessening [in production], and everything that deserves to be noted and notified[46].

During the early nineteenth-century, Carlos IV's government still encouraged trips related to chemistry applied to the arts. The most outstanding result of this policy was the first Spanish book on this subject, published in Paris by two *pensionados*: Josep Garriga i Buach and José María San Cristóbal.

Garriga had studied medicine in Montpellier at the end of the eighteenth-century and, in 1803, he was founded by the Spanish government to study dyeing technology[47]. In Paris, Garriga published several papers and reviews in influential French journals such as *Annales de Chimie* and *La Décade Philosophique*[48]. Between 1804 and 1805, Garriga and San Cristóbal published two volumes of their *Curso de Química General aplicada a las artes*, which were presented to the First Class of the *Institut de France* by Guyton de Morveau. This French chemist also wrote a very favourable review, in which he stressed that the book included the most recent developments in chemistry and praised its descriptions of scientific instruments[49]. The authors used instruments belonging to the laboratories of Alexander Charles (1746-1823) and Vauquelin, and the plates were prepared by a Spanish engraver, Manuel Esquivel de Sotomayor (b. 1777), also sponsored by the Crown to study in Paris during this period. In spite of the favourable reviews of the book, the last two volumes were never published, and neither were San Cristóbal's subsequent translation of Jean Baptiste Vitalis's book or his own textbook on dyes. Garriga kept working on dyes and wrote an important report on indigo dyes, which was positively reviewed by Gay-Lussac, Vauquelin and Berthollet at a meeting at the Institut de France in 1807[50]. Garriga was at a promising moment of his scientific life when he returned to Spain and was appointed director of dyes at an large textile factory in Segovia. However, his collaboration with the government of José Napoléon I in Spain ruined his career and he never published another substantial work on this subject. San Cristóbal escaped political persecution because he remained in Paris, but his attempts to obtain a position in Spain were unsuccessful. In 1819, he was supported by the Spanish Museum of Natural History to establish a professorship of dyeing in Madrid but again political instability frustrated San Cristóbal's mission, which, as we shall see, included reporting on several relevant French industries[51].

3.2 *Building a disciplinary identity for chemistry in Spain*

The above examples show that medicine and surgery, mining and metallurgy, artillery and industry were the motivating factors behind trips related to chemistry during the eighteenth-century. Hardly any of the trips mentioned have as their main purpose the training of future chemists. This is not surprising because in Spain chemistry was not generally recognised as an academic discipline, with its own teaching and research institutions, as it was in many European countries during the eighteenth-century. Chemistry started to gain a larger institutional space in Spain during the last third of the eighteenth-century. At that time, chemistry lectures were sponsored by the Spanish Government and other social institutions such as the *Sociedades Económicas de Amigos del País* and the *Junta de Comerç*. Moreover, chemistry was becoming more important in the curricula of Medical Faculties and Schools of Surgery and, as in other European countries, chemistry was beginning to be regarded as a part of the education of enlightened gentlemen, so that an increasing number of wealthy and leisured people attended chemistry lectures together with students of pharmacy and medicine or craftsmen.

At the end of the eighteenth-century, the government supported a Royal Chair of Chemistry, held by Pedro Gutiérrez Bueno (1745-1822) , one of the small group of important Spanish chemists who never travelled abroad during this period[52]. Infante Don Antonio Pascual de Borbón (1755-1817), the King's brother, created his own laboratory and carried out small chemical experiments, which eventually became a public chemistry course in Madrid during the 1810s[53]. In order to fill the Royal chairs created in different Spanish cities, the Spanish monarchy hired foreign chemists, such as Louis Proust and François Chabaneau, and also sponsored scientific trips to France to train future chemistry professors. The most ambitious project in this area was the Practical School of Chemistry, which was founded in Madrid at the beginning of the nineteenth-century under the directorship of Louis Proust. According to the plan of the School, six students of Proust's chemistry chair were selected to undergo advanced chemistry training in France[54]. The selected students had to spend a year studying chemistry in Paris, after which they would be appointed to one of the chemistry chairs established in various Spain cities:

> As soon as a Disciple is regarded as capable of holding a professorship, he will be appointed to one of the available chairs [...] in the Provinces and he will immediately be sent to Paris for only a year, where he will meet the most famous lecturers and note their way of teaching; he will visit the establishments related to natural history, chemistry and mineralogy, etc; he will fortify and perfect his knowledge by comparing strategies of different teachers, their systems, their schools, etc.; and, at the same time, under the supervision of the [Spanish] Ambassador, he

> will purchase the necessary books and instruments for the School [of Chemistry] to which he was affiliated [in Spain][55]

Regrettably, neither complete alumni register nor reports or exams from this institution are available - this documentation probably disappeared during the Spanish Civil War - so historians have scant evidence about the activity of the Practical School of Chemistry. Nevertheless, several documents recently found in different archives prove that, at least, a few students were trained at the Practical School and completed their studies in France. Although the plan was never completely implemented due to the Peninsular War and the subsequent political instability, many of the students found a position in industry or teaching institutions related to chemistry[56]. For instance, Gabriel Fernández Taboada (1776-1841), after studying Latin grammar and philosophy in Orense, moved to Madrid aiming to become a pharmacist. In the Spanish capital, Taboada studied chemistry and also mathematics and experimental physics. After attending Proust's lectures for four years, he was selected as one of the six disciples of the recently created Practical School of Chemistry. Once he passed the first year of practical training, he was requested, firstly, to give public chemistry lessons at the Royal School of Chemistry, and, afterwards, to spend a year in Paris improving his knowledge of chemistry. This Fernández Taboada died between 1804 and 1805. During his sojourn in Paris, Taboada published a paper in the *Journal de physique*, in which he referred to himself as an "élève de Proust" and described various chemical experiments with mercury compounds[57]. After returning to Spain, he was appointed professor of chemistry at the Nobles' Seminar in Santander (*Seminario de Nobles de la Montaña*). He moved to this city in 1807 but he was unable to give his lectures because the chemistry laboratory was never built. Taboada probably delivered lectures on other scientific topics until the Napoleonic troops entered Santander. He asked José Napoléon I's new government for another position in "one of the areas related to chemistry", such as "saltpetre, gunpowder, dyes, saltworks or glass factories", "the chemistry laboratory in Madrid" or the "Mint". This is a fair list of the available posts for chemistry students in Paris at the beginning of the nineteenth-century. As it turned out, Taboada never occupied any of the above-mentioned positions. He finally got a position at the School of Pharmacy in Santiago, where he arrived in 1811 after fleeing from the French troops in Santander[58].

Another pupil of the Practical School of Chemistry was Esteban Brunete (*fl.* 1804-1817), who after being tested by Proust and gaining his approval, was appointed professor of chemistry in Zaragoza in 1804. According to the plan of the School, he received a grant of 12,000 *reales* a year to travel to Paris, where he stayed in 1805 seeking to improve his chemical background. In September of 1807, Brunete travelled to Zaragoza to take charge of the chemistry chair of

the *Sociedad Económica Aragonesa*. A laboratory was established, several books were bought for the chair and even the Royal Cabinet of Natural History sent several boxes with duplicated mineralogical specimens to Zaragoza. In spite of these efforts, the Peninsular War frustrated Brunete's lectures. In July 1808, a government order transformed the school into military barracks. At the end of the war, Brunete left Zaragoza for good and was appointed director of the Royal Glass Factory at the Granja de San Ildefonso, not far from Madrid[59].

Many other pupils of Proust's, as well as *pensionados*, faced further problems in gaining a permanent position related to chemistry, and some of them were even persecuted for their collaboration with the Napoleonic Government during the Peninsular War. This was what happened to Josep Garriga i Buach, who was commissioned by the government of Carlos IV to study dyes with José María de San Cristóbal. Paradoxically, political persecution was the reason behind some trips to Paris, so much so that many Spanish students attending famous chemistry lectures in the French capital were, in fact, political exiles. Just a couple of trips made during the 1810s were supported by the Spanish Government: such was the case of José María de San Cristóbal and Andrés Alcón Calduch, which will be contrasted later in the paper. Both trips were related to a new institution, the Museum of Natural History of Madrid, in which the Spanish government attempted to create two chairs of chemistry. The chair of general chemistry was given to Andrés Alcón, another former student of Proust's, who was sent to France in 1819 with the main purpose of improving his knowledge of chemistry, contacting other professors, seeing and discussing their didactic methods with them and buying the required scientific instruments for his future lectures. As in other cases, political instability frustrated this ambitious plan and, due to his collaboration with the liberal government during the early 1820s, Andrés Alcón was forced into exile in London for several years[60].

But in contrast with eighteenth-century trips, Alcón and Proust's other students were sent to study chemistry and not medicine, pharmacy, surgery, mineralogy or mining. At the beginning of the nineteenth-century, chemistry in Spain had gained academic and social recognition and public lectures were introduced and supported by the government, which, in consequence, needed trained professors. As had been done in other areas, the Government sponsored scientific trips to Paris, probably the most important centre of learning and research in chemistry, in which well-known professors lectured to large audiences of national or foreign students at consolidated scientific institutions. Spanish students attended these lectures, learnt theoretical and sometimes practical chemical knowledge and also formed a disciplinary image of chemistry, which included persuasive rhetoric about the usefulness of the discipline, its relationships with other academic areas and its methods of

teaching and research. By appropriating these elements, they gained a common background which probably gave rise to an *esprit de corps* between them. At least, this is what some of their critics pointed out. In the introductory paragraphs to the plan of the Practical School of Chemistry, there were some remarks on this question:

> Experience has shown that grants awarded to learn chemistry in foreign countries often used to produce the opposite effect to that intended by the Government, because those who obtained them lost much of their enthusiasm and fondness for learning, regarding themselves as having the right to be appointed more readily than others, so that, for this reason, they impaired the hopes of those who really wanted to learn[61]

Pedro Gutiérrez Bueno, one of the few Spanish chemists who never travelled abroad, remarked in his curriculum that "without any other help but his own constant application" he was able to teach "a science which many others had studied in Paris, at the expense of the State, and which many of them never managed to teach"[62]. Other critical voices against the *pensionados* circulated in popular journals such as *Variedades de Ciencias*, *Literatura y Artes.* In 1803, an anonymous journalist compared the policy of sending *pensionados* abroad with the young student who "pretends to be wise without the fatigue that instruction costs imply". He asserted that the Enlightenment government's policy had hardly been fruitful but he qualified it as "laudable" and "necessary" in order to obtain, later on, "the just reward for such useful tasks"[63].

The criticism was not unfounded. It is not a coincidence that the three critical texts mentioned appeared at the beginning of the nineteenth-century. At that time, the crisis in the Royal Treasury, which got worse during the following years, made it very difficult for the Government to give grants for scientific trips. Moreover, because of political persecution and social and economic instability, long-term projects related to the missions of *pensionados* were doomed to failure. Trips also lost a substantial source of support due to the decline of some institutions which promoted trips during the late eighteenth-century, notably the *Sociedades Económicas de Amigos del País*. Consequently, during the first decades of the nineteenth-century, most of the trips were induced by political persecution and the rest they were privately supported at the traveller's own cost and, importantly, trips were not integrated into a general policy aiming, for instance, to improve industry or to establish chairs of chemistry. Whatever their reasons, support and purposes, travellers of this period found in Paris a more consolidated discipline of chemistry, including regular teaching methods, respected and prestigious professors and impressive teaching and research institutions.

4. SPACES OF SOCIABILITY AND LEARNING PRACTICES.

The Spanish *pensionados*' trips to France coincided with a significant transformation of public spaces for the teaching and diffusion of science, which took place in the late eighteenth-century and gained momentum during the French Revolution and Empire. The new teaching and research spaces transformed certain cities into learning sites which attracted scientific travellers from various places in Europe and America. From the point of view of chemistry, the most important centre was Paris, where foreign and local students could choose from a variety of importand old and new scientific institutions (Académie des Sciences, Jardin du Roi, École des Mines, École Polytechnique, etc.), as well as a large variety of private courses which covered a broad range of subjects. The increase of public and private teaching institutions introduced a rich diversity of learning practices, especially in areas such as chemistry, where both theoretical knowledge and practical skills in chemistry were important features of one's education. Chemical knowledge was transmitted and appropriated in very different ways in institutions such as the *Collège de France*, faculties of sciences, private laboratories, apothecaries and craft workshops or factories and nascent industrial complexes. The career routes and activities of *pensionados* offer an interesting perspective from which to explore these diverse forms of sociability associated with the learning of chemistry and related areas at the end of the eighteenth-century.

4.1 Networks of pensionados *as structures for the reception and control of newly arrived students.*

Although some Spanish travellers were able to plan their itineraries and activities according to their own personal interests, most of them were strongly afflected by the social and institutional framework of which they were part. Their activities were shaped by institutional and individual relations between the centres of origin in Spain and the reception centres in France. In some cases, the Spanish diplomatic embassy in Paris helped them to enter French academic circles or provided financial support. Moreover, the *pensionados* developed their own networks so that veteran *pensionados* gave logistic support to the newly arrived students, facilitating their accommodation in the new city or their admission to teaching or research institutions. These networks were, in some cases, means fo controlling and evaluating the students' activities. For instance, students coming from the School of Surgery of Cádiz were organised in small groups, in which the most experienced student acted as leader, supervising and reporting the activities of his fellows[64]. This was the role played by Juan Manuel de

Aréjula when he was sent to Paris between 1787 and 1789, as the leader of a group of surgical students that included Miguel Arricruz (1761-1825) and Francisco Flores Moreno (*fl*. 1787-1822)[65]. A similar group was headed by Agustín de Betancourt (1758-1824), who was in charge of several *pensionados* from the Spanish School of Engineering, including José María Lanz and Joaquín Abaitúa Barrientos (b.*ca*. 1769), among others [66].

Experienced *pensionados* supervised the training of new students. For instance, in the late 1770s the School of Mines of Almadén supported several students whoe were learning mining and metallurgical techniques in the Schools of Mines of Freiberg and Schemnitz. Before moving to these cities, students were required to spend some months in Paris, in order to improve their scientific background, mainly in areas such as chemistry. This stage of training was supervised and evaluated by trained *pensionados* already settled in Paris. Among the mining students sent to Paris by the School of Mines of Almadén were Andrés Manuel del Río (1765-1849), Fernando Casado de Torres (d. 1829) and José Ricarte (*fl.* 1792). After evaluating their scientific background and studies, Fausto de Elhuyar, who had been appointed to supervise the group, reported to the Minister José Gálvez that the three new *pensionados* had to stay in Paris for an extended period in order to reach a good level of expertise in chemistry and mechanics[67]. Afterwards, Ricarte and del Río helped the new *pensionados*, Manuel de Angulo (b. *ca.* 1760), Juan López de Peñalver (*fl.* 1788-1835) and José Miaja Pingarrón (*fl.* 1788-1825), with some logistical problems, such as obtaining a temporary residence permit or introducing them to professors of the Academy of Mines[68].

Political networks were also important for some Spanish travellers, especially for those who were forced into exile due to their ideological affinities or political activities during the rule of the absolutist King Fernando VII (1814-1833). Most of the exiles arrived in France after the Peninsular War or the brief liberal period (1820-1823) and the French police maintained regular surveillance over their activities and movements inside France. As a result, an enormous number of files with police reports accumulated. Some of them are still held in the French National Archives, offering interesting but still underused sources of historical analysis. In these files, there is substantial information about the political networks of the travellers, the lectures they attended and their political leanings[69].

4.2 Chemistry in old and new learning venues.

In spite of these constraints, *pensionados* and exiles had a broad range of possibilities open to them when looking for chemistry training. The plurality

and transformation of chemistry teaching venues in Paris revealed degrees of freedom which prevented absolute control of their activities, offering them different choices in their academic careers. Their choices were, therefore, shaped by their interests and the characteristics of the various public and private lectures on chemistry in Paris. The institutional reforms carried out in France during the Revolution and throughout the Empire were crucial in defining the main features of the organisation of science in the country during the nineteenth-century. The changes were especially important in the case of chemistry. Lectures were introduced in the new secondary schools (*lycées*) as well as in the new higher teaching institutions such as the Faculties of Sciences, the *École Normale Supérieur* or the *École Polytechnique*. Other institutions such as the Faculties of Medicine were reformed, so that chemistry lectures gained importance in the medical curriculum; and, last but not least, the apothecaries' apprenticeship was transformed with the new Schools of Pharmacies, in which chemistry chairs were also established[70].

These changes did not have the same dramatic consequences in areas such as mathematics or astronomy – included in the *Collèges* of the *Ancien Régime* and in the University syllabus – when compared to other less institutionalised areas such as chemistry, which had previously been almost non-existent in secondary education and little studied in the Universities. The new institutions opened new venues for the diffusion and practice of chemistry, in parallel with private laboratories or apothecary workshops. The new institutions did not, however, eliminate private lectures and, in some cases, they even encouraged them. During the first decades of their existence, Faculties of Sciences focused their activity on delivering exams and granting degrees but not on training. As a result, preparatory courses for the *baccalaureat-ès-sciences* exam flourished in private academies in Paris, mainly after this degree became compulsory in order to be accepted by a Faculty of Medicine. In a similar way, the Schools of Pharmacy did not replace the old apothecary apprenticeship, which was still important in the mid nineteenth-century.

In fact, some of the most famous new institutions, such as the *École Polytechnique* and the *École Normale*, played a minor role in the learning paths of *pensionados* and Spanish exiles. Thers is just one case where we have evidence of studies in these institutions: Alcón Calduch, whose trip was funded by the Spanish Museum of Natural History, was admitted to the *École Polytechnique* thanks to the support of the Spanish ambassador. In his report, Calduch mentioned that he was "the only foreign person who was allowed to enter the school"[71]. Being a military institution, the access to the *École Polytechnique* was difficult for foreigners, even if some of them, such

as Calduch, succeeded in being admitted[72]. There is also a small number of Spanish travellers in the alumni registers of the Faculty of Sciences. These trips were not supported by training programmes implemented by Spanish teaching institutions and governmental offices but the result of personal circumstances, generally related to politics. That is the case of José Luis Casaseca (1800-1869), son of a Spanish exiled *afrancesado* who arrived in Paris just after the end of the Peninsular War and the fall of José Bonaparte's government. As a result, Casaseca obtained an excellent scientific education at the Parisian *Lycée Henry IV*, and afterwards attended lectures at the Faculty of Sciences, obtaining the sciences doctoral degree[73].

As we have said before, during the eighteenth-century a substantial number of Spanish students attended lectures and were awarded medical degrees at French universities, mainly in Paris and Montpellier. Catalan students took advantage of the grants given by the Girona council, which supported the *College of Girona* at Montpellier. There were also Spanish students attending the courses of the Faculty of Medicine in Paris. During the Revolution and throughout the Empire, chemistry gained importance in medical curricula and prominent chemists such as Fourcroy and Vauquelin lectured on chemistry at the Paris Medical Faculty, making this institution more attractive for Spanish *pensionados* interested in chemistry. At the beginning of the nineteenth-century, Josep Garriga i Buach, who had studied medicine in Montpellier, attended some lessons at the Parisian Faculty of Medicine together with other Spanish travellers such as Luzuriaga, a member of a family of prestigious Basque physicians who studied at the Faculty of Medicine, the Schools of Surgery and the *Collège Royal* in Paris[74]. Among the Spanish medical students interested in chemistry, the most famous was Mateu Orfila, who registered as a student at the Paris Medical Faculty in 1807. At least twenty Spanish students were registered in the alumni register of the Paris Medical Faculty during the 1810s and 1820s[75].

Despite the importance of these institutions, Spanish travellers preferred to attend chemistry lectures at other locales. They mostly frequented the *Collège de France* and the *Muséum d'Histoire Naturelle*, where lectures were public and not part of a larger official curriculum, so they could be followed as independent courses. From the last decades of the eighteenth-century, chemistry lectures at the *Collège de France* attracted a heterogeneous audience which included mostly medical and pharmacy students, but also artisans, gentlemen and enlightened wealthy notables ("gens du monde"), fascinated by chemical demonstrations. Spanish students regarded these lessons as an accessible way to complete their chemistry background. They were looking for both practical and theoretical lectures in

which chemistry was presented as an organised and systematic body of knowledge. Their presence dates from the 1780s, just after the creation of the first professorship of chemistry, held by Jean Darcet (1725-1801). Several *pensionados* from the Basque Economic Society studied with Darcet, such as Jerónimo Mas, who travelled to Paris in order to set up a course of chemistry in Bergara and acquire scientific instruments for his lessons. Jerónimo Más performed several experiments on "the composition and decomposition of water" with Léfevre of Guineau (1751-1829), professor of experimental physics, and Jérôme Dizé (b. 1765), Darcet's assistant at the laboratory of the *Collège de France* since 1784. In this way, the Spanish teacher performed this famous water experiment himself, employed by Lavoisier's followers to disseminate his new ideas on combustion. After the French Revolution, which introduced minor changes in the *Collège de France*, Spanish travellers continued to fill its lecture hall, representing for some years almost half of the audience[76].

Apothecary workshops continued to play an important role in the teaching of chemistry during the first decades of the nineteenth-century. Although it is difficult to gather historical evidence on this type of training, Spanish students do not seem to have chosen a course of training which compelled them to practice pharmacy with a *maître* for several years. This training option was only followed by some exiles who found sanctuary in France. Thanks to police reports, we know that in 1809 Francisco Evangelista, who studied medicine in the city of his birth, Salamanca, and was taken prisoner in France during the Peninsular War, was taken on as an apprentice in the pharmacy of Mr. Landreau, in Angoulême, where he stayed until 1814. Like other provincial pharmacy students, he moved to Paris to complete his training and attended various courses on chemistry and botany, some of them at the *Muséum d'Histoire Naturelle*. Finally, in 1816, he was "reçu Maître en Pharmacie". Some years later, Evangelista attended Orfila's chemistry courses and became his *preparateur* [77].

Orfila's private lectures became very popular during the 1810s. He started delivering private lectures on physics and chemistry during his years as a medical student in Paris in a laboratory equipped by a wealthy friend[78]. The war between France and Spain deprived Orfila of his grant and encouraged him to organise new private scientific courses which were to become his main source of income[79]. During the winter of 1812, Orfila taught chemistry to a group of forty students. The following year he moved to a new laboratory, where he went on lecturing on chemistry and other subjects, such as legal medicine, botany and anatomy, for more than three years[80]. He also applied for a post as a teacher of physics and chemistry in one of the Parisian *Lycées* but, despite being supported by Vauquelin, Haüy

and Thenard, he was not accepted[81]. In 1817, he replaced Louis Jacques Thènard (1777-1857) as lecturer in the chemistry at the *Athénée* of Paris and published his *Elémens de chimie médicale*, aimed at the "medical and pharmaceutical students" attending his private lectures on chemistry[82]. Orfila's lectures soon became an attractive destination for Spanish *pensionados* such as Evangelista and Carlos Ardit.[83]

Private scientific lectures were, in fact, very common in Paris and perhaps one of the main things that attracted students from other parts of France, Europe and America. The teachers were among the most famous chemists of the time. Fourcroy announced in the *Décade Philosophique* his "Experimental Course on Chemical Philosophy", delivered in 20 sessions[84]. The young Thenard, teacher of many Spanish *pensionados*, offered preparatory courses to the *École Polytechnique* for 20 francs per month and claimed to train his students in "chemical manipulations" of substances, their use "in the arts" and "mineral, vegetable and animal" analysis[85]. Many courses were conducted by young students, pharmacists or physicians such as Orfila, who realised that the enormous student community of Paris was a potential clientele for his courses. And, like Orfila, many chemistry teachers delivered their lectures to medical students of the Paris Faculty of Medicine. In 1818, a students guide to the Faculty of Medicine in Paris recommended courses at institutions such as the *École de Pharmacie* and the *Collège de France* as well as private courses in anatomy, physiology, medicine, surgery, etc. given by teachers such as Jean Marjolin (1780-1850), Nicolas Adelon (1782-1862) and François Magendie (1783-1857). The guide also recommended private chemistry courses taught by Vauquelin, Orfila and Laurent Sallé[86]. In the *Almanach général de médecine* of 1827, a great number of private courses were reported, including courses on medical chemistry given by Marie Guillaume Devergie (1798-1879), chemistry applied to the arts by Henry François Gaultier of Claubry (1792-1878) and general chemistry by George Sérullas (1774-1832) [87]. These private courses were encouraged by members of the Parisian Faculty of Medicine to such an extent that spaces in the faculty building were reserved for the classes. According to Orfila, dean of the Faculty, this system fostered pedagogical innovation:

> I strongly support this system, which complements the syllabus to be taught by the Faculty during the year and stimulates a useful competitive spirit among teachers who will always be wary of allowing themselves to be overshadowed by young rivals; in short, within the bounds of reason, this is the principle of academic freedom so often insisted upon."[88]

In his book on American students in Paris during the nineteenth-century, John Warner showed that private instruction became a valued core of their

training in medicine, especially in areas such as clinical instruction, in which they wanted to learn practical skills and obtain their own sensory experience at the patients' bedside. In some cases, a small group of students arranged with an *interne* to admit them to his wards and, in return for a fee, the *interne* pointed out interesting cases, allowed the students to examine patients and answered questions[89]. There is evidence that Spanish chemistry students also preferred these private courses, perhaps because of their brief duration –which fitted better with their temporary sojourn in Paris – and the chances they offered for access to chemical manipulations. In some cases, like American medical students, they were employed in public teaching institutions and laboratories, and thanks to arrangements with *preparateurs* or *adjoints*, they gained access to places that were not attended by regular students. A good example is Antonio Benito, a Spanish lawyer who collaborated with José Napoleon's government and, as a result, was compelled to seek exile in Paris in 1814. He decided to study "chemistry and mineralogy" and attended Sage's lectures at the Mint House, but he soon realised that these lectures were out of date. Seeking to improve his chemical knowledge in "a brief period of time", he convinced himself that private lessons were necessary and he contacted the young chemist Gaultier de Claubry , who had joined Thenard in his courses at the Faculty of Sciences[90]. Benito took two or three lessons a week for a year, paying Gaultier the laboratory running costs plus four francs per lesson. According to Benito, Gaultier used for his lessons Thenard's chemistry laboratory – probably at the *Collège de France* – which private students could use even after the end of courses. Benito also had access to some of the instruments belonging to the "rich cabinet of Physics" considered as "indispensable [...] at least for the first lessons in chemistry"[91].

Many other Spanish travellers probably took private courses such as those already mentioned, but the evidence is scarce. The main problem faced when following private courses is the scant number of historical sources which can be employed to analyse their contents, didactic practices or even the number of students and their profiles. We find a similar problem for other important chemistry learning places attended by Spanish travellers: craft workshops and factories where *pensionados* tried to improve their knowledge of "chemistry applied to arts and industry".

4.3 Industrial Espionage and Technological Transfer.

As mentioned above, a significant number of travellers were required to learn technological processes related to dyes, metallurgy or mining. In this case, the learning scenarios were completely different from public lectures at

the famous teaching institutions of Paris. To begin with, relevant workshops and factories were scattered all over French territory. Travellers interested in dyeing technology, such as José María de San Cristóbal or José Garriga i Buach, could not expect to obtain this knowledge during a brief stay in Paris or by reading the main chemistry textbooks and journals. They were compelled to travel from one dyeing centre to another, negotiating with dyers their admittance to their workshops to observe procedures and routines. San Cristóbal and Garriga, as well as other *pensionados*, also attended public lectures in Paris, so they were faced with very different ways of appropriating chemical knowledge. In order to compare these extreme situations, let us focus on two trips that were supported in 1819 by the same Spanish institution: the Museum of Natural History in Madrid.

The first traveller was Andrés Alcón Calduch (1782-1850), son of a chemistry demonstrator at the University of Valencia, who studied with Louis Proust at the beginning of the nineteenth-century. After obtaining his degree in pharmacy, he was appointed chemistry professor at the School of Pharmacy of Madrid in 1815 and, three years later, he held the new chair of chemistry at the Natural History Museum of Madrid. During the first years in his new position, Alcón focused on the organisation of the laboratory and the acquisition of chemicals and teaching instruments. As a part of these activities, he was sent to Paris in 1819, where he visited chemical factories, "chemistry and physics laboratories and cabinets" and the School of Mines. According to Alcón's report, he used to approach professors before the beginning of their lectures that they could give him an advance idea about lesson contents and methods. Among the chemists and teachers he contacted were some of the most famous French chemists, such as "Vauquelin, Thenard, Deyeux, Laugier, Gay-Lussac, Biot, Haüy, Brongniard, Say, Clement-Desormes, Thouin, Bertholet and others..."[92]. Through this intense social activity, Alcón succeeded in attending the assemblies of the *Institute de France* and the classrooms of the *École Polytechnique*[93]. By the end of 1819, Alcón Calduch also attended chemistry lectures at the Faculty of Sciences, the Faculty of Medicine and the *Collège de France* as well as some courses of physics[94]. In his report, Alcón also pointed out that social relationships allowed him to have access to the private laboratories of some important chemists. He used this information, as well as informal talks with professors, to organise his future chair of chemistry and the teaching laboratory at the Natural History Museum of Madrid. Moving in this academic arena of public knowledge, Alcón, a young Spanish chemistry teacher, would find it easy to access very different venues, ranging from chemistry lectures and scientific discussions held in the *Institute de France* to private spaces such as personal laboratories.

His colleague, José María de San Cristóbal, who also obtained a grant from the Museum of Natural History, had a very different experience. In September 1819, he travelled to France to learn dyeing technology, so that, when back in Spain, he could lecture on "the most elaborate procedures of this important art and disseminate the scientific principles on which it is founded"[95]. San Cristóbal visited several chemical plants in Bordeaux, Limoges, Orléans, Rouen and Louviers. In Louviers, an important city in the textile industry, San Cristóbal succeeded in "attending one of the best dyeing workshops every day", in which, besides practising regular dyeing procedures, he was able to perform "a series of experiments" with dyes[96]. San Cristóbal remarked that the art of dyeing "can be learned just in the workshops (*obradores*)" but it was difficult to be accepted in these secret places and even more complicated to collect useful information, that is, "to observe craft operations, to be informed about different procedures and to practise"[97]. In a report, San Cristóbal described the strategies he employed to overcome these obstacles:

> To travel from one place to another, verifying beforehand the names of the principal patrons of manufactures, seeking for some recommendations that, in most cases, are useless; spending much time on gaining the trust of the most accessible workers, before penetrating what we shall call the sanctuary of the arts and conferring with its ministers [...]. [Besides these problems] one must add giving tips to workmen and what is extremely useful – or to be perfectly honest, absolutely necessary – making arrangements with master craftsmen so that they will allow us to observe, ask and act freely, otherwise it is impossible to achieve one's goal.[98]

Simultaneously, San Cristóbal prepared a translation of a textbook on dyes which was written by a professor of chemistry applied to the arts in Rouen, Jean-Baptiste Vitalis (d. 1832). He enriched the translation with "instructions about textile bleaching" and other additions, owing to his friendship with Vitalis[99]. San Cristóbal visited several factories in the North of France and, in Sedan, made an agreement with a craftsman who, in exchange for a fee of 12,000 *reales* (half of San Cristóbal's annual salary), promised to unveil to him "the secret of his precious procedures" and to allow him to work in his workshop. But political instability in Spain frustrated San Cristóbal's projected chair of dyeing "grounded not on uncertain recipes, nor only on tradition, but founded on the scientific principles of chemistry"[100]. San Cristóbal claimed that such a chair would perhaps never be created in Spain, considering that seldom "does a chemist become a craftsman or a craftsman become a chemist"[101]. Like his colleague Alcón Calduch, San Cristóbal was probably ostracised by the subsequent Spanish absolutist governments[102].

In contrast to Alcón Calduch's experience, San Cristóbal's struggles to collect craft information about dyes seemed more a mission of industrial

espionage than an academic trip. However, the use of the term "espionage" might be ambiguous and veil our understanding of San Cristóbal's experiences in the complicated area of chemistry applied to arts and factories. In fact, as well as other chemists interested in this area, such as Jean Antoine Chaptal, San Cristóbal was trying to gather craft information, which was strictly controlled by traditional rules of transmission and learning, and to make it public through public lectures and textbooks. In this way, he was developing one of Chaptal's main objectives for the enhancement of chemistry applied to the arts:

> Before chemistry was restored to general principles, the many operations of industry, factories and workshops were, so to speak, the prerogative of a few nations and the property of a small number of individuals; the greatest secrecy wrapped each process in a veil of mystery; formulas and procedures were handed down from generation to generation. Chemistry has unveiled it all: it has turned the realm of arts into the heritage of us all; and, in a short period of time, we have seen how all the people who have cultivated this science have improved the establishments of their neighbours. Preparations of lead, copper and mercury; works on iron; the manufacture of acids; dressing of cloths; printing of colour on textiles; the composition of glass, earthenware and china, etc.; all these things have been brought out into the open, and are common property today. [103]

Like San Cristóbal, many other *pensionados* travelled to France for this purpose during the first decades of the nineteenth-century. Josep Garriga i Buach, co-author with San Cristóbal of a textbook on chemistry applied to the arts, visited several factories in France, collecting information about indigo dyes, their manufacture and operation. He finally reported his results at a public session of the Paris Academy of Sciences in 1807. Vauquelin, Gay-Lussac and Bertholet, referees of Garriga's memoir, remarked on the great obstacles that Garriga had to overcome in order to learn the "operations of the art of dyeing" and to practise them "in different workshops and in different parts of France"[104]. Could one employ the term "industrial espionage" to describe an activity whose details were openly described by its author in the main scientific institution of the country in which the mission was carried out?

Other trips of Spanish *pensionados* fit better into the term "industrial espionage". Perhaps the most representative one was that of Eugenio Izquierdo (*fl.* 1770-1814) who stayed in Paris during the 1770s and 1780s studying chemistry and natural history thanks to royal financial support. Izquierdo, who was appointed first vice-director and afterwards director of the Royal Cabinet of Natural History, was a freemason who assisted several *pensionados* from the Basque Economic Society to find accommodation in Paris and who probably introduced them to Freemasonry[105]. Izquierdo was,

in fact, carrying out several missions of industrial espionage and he was in touch with several French spies in Britain. In 1785, he made a deal with the French spy Le Turc in order to introduce a new English stocking loom in Spain[106]. Le Turc succeeded in transporting the machine and several specialised workers to France, where he left them with Francisco Angulo, future vice-director of the Spanish Royal Cabinet and professor of chemistry, who was apparently living at Izquierdo's house in Paris at that time[107]. In spite of the problems between the French and Spanish spies, Izquierdo purchased the new loom and ordered twelve more of the same type. According to Le Turc, Izquierdo had a free hand to send looms of several types to Spain. Izquierdo had been appointed Director of the Rocheguyon Company, a group of aristocratic or wealthy partners, including the Duc de Rochefoucauld, the Duchesse d'Anville and the financier Lecouteulx.[108] Izquierdo also collaborated with Le Camus de Limary, another French spy who introduced English copper sheathing in France. Izquierdo provided additional capital for Le Camus's firm and he also described to Le Camus the latest progress on Watt's steam-engine. According to Le Camus, Izquierdo had been to Cornwall, where he had "observed and admired" Watt's engines[109]. At the same time, between 1786 and 1788, Izquierdo co-operated in several tasks related to the establishment of a chemical laboratory in Madrid[110]. These activities and his post as director of the Royal Cabinet helped him to hide his espionage activities, but eventually they were discovered. In 1798, the French Republican Government arrested Izquierdo after intercepting some compromising letters. In a report addressed to the Spanish Government, the Spanish Ambassador in Paris, Nicolás de Azara, remarked that Izquierdo was an appropriate agent for a espionage mission in France because he was able to use his fame and contacts inside the French academic community. Azara also mentioned that a prominent member of the French Government accused Izquierdo of having used "science to serve politics"[111].

The use of scientific missions to hide industrial espionage was a practice that we found in other cases, for instance, in the Elhuyar brothers' trips. During the 1770s, Fausto (1755-1833) and Juan José de Elhuyar (1754-1796) spent several years in Paris, where they attended lectures given by Hillaire Marin Rouelle (1718-1779) at the *Jardin du Roi*. They also contacted Jean D'Arcet (1725-1805), professor of chemistry at the *Collège de France*, as well as other Basque *pensionados*. Just after returning to Bergara, Juan José de Elhuyar was entrusted with a mission supported by the Spanish Navy Department in conjunction with the Basque Society. He received two documents with two sets of instructions, one open ("instrucción ostensible"), the other secret ("instrucción secreta")[112]. The open instructions

pictured Elhuyar's mission as a purely scientific trip supported by a private institution, the Basque Society. According to these instructions, Elhuyar not only had to attend lectures in Paris and Freiberg but also had to contact a prominent German iron smelter, with whom he had to "engage in a close personal relationship in order to find out his achievements". He was also requested to visit ironworks and foundry furnaces and report on "everything" he saw[113]. The secret instructions required him to focus his activities on the manufacture of military cannons, including a final trip to Scotland. He was to consult various French scientists in Paris and then study at the School of Mines in Freiberg, where he was to collect information about cannon foundries in Saxon and Sweden. Finally he also had to learn German so that he could act as if he were a good German foundry worker whose activities in Britain would be above suspicion. In Britain, he joined Ignacio de Montalvo (*fl.* 1787-1781), a Bergara silver-smith acting as an industrial spy, who succeeded in entering the famous Scottish Carron ironworks, seeking technological information related to naval cannons. José Elhuyar never met Montalvo in Carron, but he travelled to Central Europe, attended the lectures given by Abraham Gottlob Werner at the Freiberg School of Mines, and visited Torbern Olaf Bergmann in Uppsala[114]. This latter encounter was very significant for Elhuyar's career, for it led him later on to the discovery of wolfram (tungsten)[115]. A failed espionage venture that ended up producing the most celebrated scientific achievement of the Spanish *pensionados*!

This example clearly reflects the interplay of academic or scientific trips and secret missions of industrial espionage, especially in the case of disciplines such as applied chemistry, mineralogy, metallurgy and mining. The disciplinary borders and structure of chemistry were in the process of negotiation during the eighteenth-century as was its relation to other disciplines (medicine and pharmacy, for instance) and industrial arts. As a result, chemistry travellers crossed not only geographical and political borders but also cultural frontiers between scientific and technological traditions with very different norms and values about what was considered as private or public information, training and expertise. During the same trip, they had probably visited academic institutions, freely attended public chemistry lectures and bribed craftsmen to gain access to their workshops. In each of these situations they came across very different values regarding the transmission of knowledge and practices of teaching and learning. In other cases, the scientific façade of the trip was an excellent strategy to veil secret – and more important – espionage motives. In this sense, expressions such as "purely scientific interests", "technologically oriented" or "industrial espionage" may be misleading labels, which obscure rather than clarify our historical understanding of the *pensionados*' activities.

5. CONCLUSIONS

Spanish *pensionados* and exiles offer us a broad range of cases through which to study how science was appropriated from one geographical context to another. Their names are scarcely mentioned in important narratives concerning the history of chemistry and, apart from a few cases, their lives are hardly attractive for hagiographic purposes. Although some *pensionados* are usually mentioned by early twentieth-century Spanish chemist-historians and they played a major role in recent historiography on the Spanish Enlightenment, many of their biographies have not yet been studied in depth. In this study, we have offered some conclusions from a collective study of a large sample of travellers who spent many months or years studying chemistry in Europe during the late eighteenth and early nineteenth centuries. The reasons and interests underlying their trips changed during the three periods under study as well as their places of destination and itineraries.

During the last third of the eighteenth-century, travellers were supported by government institutions or economic societies which aimed to revitalise and implement chemical knowledge, as a means of developing medical theory and practice as well as many industrial arts. Therefore, the main institutions which backed travellers were surgical schools, on the one hand, and economic societies and the government, on the other. The main aim was not chemical theory per se but its applications to medicine and industry. These goals undoubtedly shaped the way in which the "chemical revolution" was perceived and appropriated in Spain. When they returned to Spain, many travellers joined teaching institutions or were appointed to key positions in royal factories or Trade Boards. Thus, they could spread their newly gained knowledge, values and skills through chemical lectures, textbooks, journals and institutional reforms.

Many elements of the second group of travellers, especially those who visited Paris during the first years of the nineteenth-century, were supported by the Spanish government to study chemistry in order to became chemistry teachers on the return to Spain. However, the economic and political crisis and the unfavourable context of the Napoleonic wars severely hampered their careers as well as governmental plans. In addition, political persecution against Napoleonic and liberal government supporters led many scientists to be ostracised or sent to exile in France and England. Many exiles attended chemical courses in Paris and a small group even followed important scientific careers in France, but they encountered great difficulties when they attempted to return to Spain to secure positions in academic establishments. In consequence, despite their advanced training and expertise in chemistry, their trips did not have any impact on Spanish society as they hardly

published any textbooks or papers in Spanish journals or participated in any teaching institutions.

The travellers visited many different places and they put forward diverse strategies to gain the theoretical and practical knowledge they were looking for. Some of them attended scientific and teaching institutions and got in touch with many famous French chemists. The most visited scientific centre in this period was the *Collège de France*, which offered many advantages to Spanish visitors thanks to the open character of its lectures. Other travellers attended chemistry lectures by private tutors, who allowed them to obtain practical training in their laboratories. Our study clearly shows that private chemistry courses played an outstanding role during this period, and many young chemists, such as Mateu Orfila, were able to start and maintain a scientific career in chemistry. Finally, other groups of travellers, who were mainly interested in technological aspects, visited not only public and private teaching institutions but also industrial factories and craft workshops. In this case, they faced coercive rules regarding the transfer of technological information and their trips turned out to be real spying missions. It should be kept in mind, however, that there was a continuous spectrum of activities ranging from tours apparently seeking the appropriation of scientific knowledge to expeditions of blatant spying. In fact, there are many intermediate cases ranging from travellers with a mixed agenda, with both scientific and industrial goals, to travellers who used their scientific background to hide political or industrial spying missions.

The plurality of motivations, activities and training strategies illustrated by this sample of scientists and travellers is no doubt a reflection of the diversity of contexts in which chemistry was practised and taught throughout the period under study. Scientific trips constitute an excellent topic for the analysis of different forms of production, circulation and appropriation of scientific and technological knowledge during a period in which new instruments and forms of communication appeared, dramatically transforming scientific activity.

The trips of Spanish *pensionados* also offer us an occasion to reflect on the use of the categories of centre and periphery in studies on the transmission of science. The idea of an outside space providing scientific and technical knowledge appears in our study as a diffuse and controversial category that is both historically and historiographically constructed. For our historical actors this outside space was not identified with particular centres. We find rather a plurality of places – cities, schools, factories and industrial sites – linked by a diversity of lines drawn by the *pensionados*' and exiles' itineraries. Places and itineraries that had, moreover, different meanings according to travellers' interests. Paris, a city that might be considered as a centre, actually appears in travellers' narratives and activities with very

different meanings, running from the main destination for medical students interested in chemistry to just a first step on trips motivated by other aims such as mining and metallurgy. Paris, or any other destination, turned into a centre only in our actors' minds according to their professional expectations, scientific interests and even political ideas. As we have shown, scientific relations with foreign countries, and especially with France, were rhetorically transformed into an object of political and ideological controversy. Territories and people from the other side of the Pyrenees became the main source of progress and modernity for travellers and their supporters and a dangerous focus of strange perverting ideas and mores for their more radical detractors. This polarised and Manichaean image of international scientific relations was reinforced and elaborated by several generations of historians who identified themselves with the political and scientific situation lived by our historical actors. All of them contributed to shaping the idea of a central source of knowledge that spread like an oil slick through an immaculate periphery. These categories should remain, therefore, as historical constructs rather than historiographical tools.

Notes

Abbreviations
Archivo Histórico Nacional, Madrid (AHN)
Archivo General de Simancas, Simancas (AGS)
Archivo del Palacio Real, Madrid (APR)
Archivo del Museo de Ciencias Naturales, Madrid (AMCN)
Archives du Collège de France, Paris (ACF)
Archives Nationales de France, Paris (ANF)

[1] The word *pensionado* was employed to refer to travellers who were supported by Royal Governments or private institutions.

[2] For an introduction to the history of science during the Spanish Enlightenment, see M. Selles, J.L. Peset; A. Lafuente, *Carlos III y la ciencia de la Ilustración* (Madrid: Alianza Editorial, 1987), and J. Fernández Pérez; I. González Tascón (eds.), *Ciencia, técnica y estado en la España Ilustrada* (Zaragoza: MEC, 1990). About scientific trips, see A. Lafuente, "Las políticas y los métodos de internacionalización de la ciencia española durante el siglo XVIII", *Revista de Occidente* (1988), 229-42; M. Valera; M. López Sánchez; C. López Fernández, "Científicos españoles en el Reino Unido (1750-1830)", *Asclepio, 50* (1) (1998), 49-68, and A. García Belmar; J.R. Bertomeu Sánchez, "Viajes a Francia para el estudio de la química, 1770-1833", *Asclepio*, *53* (1) (2001), 95-135.

[3] For a discussion of some images related to the chemical revolution, see B. Bensaude-Vincent," Between History and Memory: Centennial and Bicentennial Images of Lavoisier," *Isis*, *87* (1996), 481-499. A survey of recent trends in A. Donovan (ed), "The Chemical Revolution: Essays in Reinterpretation", *Osiris*, *4* (1988), 1-236 and P. Bret, "Trois

décennies d'études lavoisiennes. Supplément aux bibliographies de Duveen", *Revue d'histoire des sciences*, *48* (1/2) (1995), 169-197.

[4] On the chemical revolution in Spain, see R. Gago's works, which include references to former historical research by Spanish "chemist-historians" such as Bonet i Bonfill, Rodríguez Carracido and Moles Ormella. See R. Gago, "La enseñanza de la química en Madrid a finales del siglo XVIII", *Dynamis*, *4,* 1984, 277-300; *id.* "The New Chemistry in Spain", *Osiris*, *4,* 1988, 169-192 and *id*. "Cultivo y enseñanza de la química en la España de principios del siglo XIX". In: J.M. Sánchez Ron (ed.), *Ciencia y sociedad en España* (Madrid: El Arquero, 1988), pp. 129-143.

[5] F.L. Holmes, *Eighteenth Century Chemistry as an Investigative Enterprise* (Berkeley: University of California, 1989).

[6] B. Bensaude-Vincent, B.; F. Abbri, *Lavoisier in the European Context. Negotiating a New Language for Chemistry* (Canton: Watson Publishing International, 1995).

[7] K. Hufbauer, *The formation of the German chemical community, 1720-1795* (Berkeley: Univ. of California Press, 1982).; F. Abbri "Chemistry turned outside down: Aspects of the Italian debate on Lavoisier's theory". In: F. Abbri; F. Crispini (eds.), *Atti del IIIº Convegno Nazionale di Storia e Fondamenti della Chimica* (Cosenza: Brenner, 1991), 101-111; and M. Beretta, "Gli scienziati italiani e la rivoluzione chimica", *Nuncius*, *4* (2) (1989), 119-146.

[8] Good examples are papers such as H. Guerlac, "The Continental Reputation of Stephan Hales, *Archives Internationales d'Histoire des Sciences*", *4* (1951), 393-404. These and other works have paid attention to travellers such as João Jacinto de Magalhães (1722-1790). See I. Malaquias; M. Fernandes Thomaz, "Scientific Communication in the 18th century: The case of John Hyacinth de Magellan", *Physis*, 31 (1994), 817-834.

[9] One of the most studied cases is that of Martinus van Marum, who established several contacts with a number of Parisian scientists, and especially Lavoisier, during his trip in 1785. See T.H. Levere, "Martinus Van Marum (1750-1837): The introduction of Lavoisier´s Chemistry into the Low Countries", *Janus*, *53* (1966), 115-134 and H.A.M. Snelders, "The New Chemistry in Netherlands", *Osiris*, *4* (1988), 121-146. For other studies showing the role of individual travels in the transmission of the chemical revolution see, for instance, A. Lundgren, "The New Chemistry in Sweden", *Osiris*, *4* (1988), 146-169, in which the travels of Pehr Afzelius, co-author of the Swedish translation of the new nomenclature, are studied. See also A.S. Jacobsen, "A.W. Hauch's Role in the Introduction of Antiphlogistic Chemistry into Denmark", *Ambix*, *47* (2) (2000), 71-95.

[10] Due to the similarities with our study, studies on Portuguese "estrangeirados" are particularly valuable for a comparative view. See A. Simoes; A. Carneiro; M.P. Diogo, "Constructing knowledge: Eighteenth-century Portugal and the new sciences". In: K. Gavroglu (ed.) *Sciences in the European periphery during the Enlightenment* (Dordrecht: Kluwer, 1999), 1-40; M.P. Diogo; A. Carneiro; A. Simoes, "Sources for the History of Science in Portugal: one possible option", *Cronos*, *3* (1) (2000), 115-141, and other papers quoted therein. See also their chapter on this volume.

[11] For a detailed description of the sources and methodology, see A. García Belmar, op. cit. (2).

[12] All graphs have been made using available biographical information from different sources. In order to avoid possible bias in Graph I, II and III, authors with only archival information have been excluded. For the case of trips around different places, each country visited has been individually considered.

[13] H. Guerlac, *Lavoisier - The crucial Year. The Background and Origin of his First Experiments on Combustion, in 1772* (Ithaca, Cornell University Press: 1961) and F.L. Holmes, *Antoine Lavoisier - The Next Crucial Year* (Princeton: Univ. Press, 1997).

[14] See C.E. Perrin, "The Triumph of the Antiphlogistians". In: *The Analytic Spirit. Essays in the History of Science in Honor of Henry Guerlac* (Ithaca and London: Cornell University Press, 1981), pp. 40-64 and B. Bensaude-Vincent, *Lavoisier. Mémoires d'une révolution* (Paris: Flammarion, 1993).

[15] AHN, *Consejos*, file 1289. Letter by the Conde de Floridablanca addressed to the Consejo de Castilla. "El Rey ha determinado que ninguno de sus vasallos salga a educarse a países extranjeros sin motivo ni permiso de S.M."

[16] On these subjects, see M.S. Oliver, *Los españoles en la revolución francesa* (Madrid: Renacimiento, 1914); R. Herr., *España y la revolución del siglo XVIII* (Madrid: Aguilar, 1988); J.R. Aymes (ed.), *España y la revolución francesa* (Barcelona: Crítica, 1989) and J.R. Aymes, "Españoles en Francia (1789-1823): Contactos ideológicos a través de la deportación y el exilio", *Trienio*, *10* (1987), 3-26.

[17] The *afrancesados* were a small but influential group of Spaniards who collaborated with José Bonaparte's government. They attempted to adapt many French scientific institutions to the Spanish context and, in some cases, they developed old Enlightened projects. On these projects see J.R. Bertomeu Sánchez, *La actividad científica en España bajo el reinado de Jose I (1808-1813) (*Valencia: Universitat de Valencia, 1995) and J.R. Bertomeu Sánchez,; A. García Belmar, "Tres proyectos de creación de instituciones científicas durante el reinado de José I: Un estudio sobre la transmisión de la ciencia en el marco de la Guerra de la Independencia". In J.A. Armillas (ed.) La *Guerra de la Independencia. Estudios* (Zaragoza:. Diputación, 2001), vol. I, pp. 301-325.

[18] On Spanish liberal exiles, see V. Lorens, *Liberales y Románticos. Una emigración española en Inglaterra.*. (Madrid: Castalia, 1979), and R. Sánchez Mantero, *Los liberales en el exilio* (Madrid: Rialp, 1975). For a general view of Spanish scientific trips to Britain, see VALERA, *op. cit.* (2).

[19] "Les jeunes gens suivent avec ardeur mon cours sur la chimie animale à l'école de médecine. Rien n'égale leur envie d'apprendre; les vingt leçons que je fais sur cette partie si neuve de la chimie, donnent, je le vois, un grand mouvement à cette branche de l'étude de la nature; mais je le modère le plus que je le puis; je ne veux pas trop l'accélérer, de crainte de briser cette belle machine entre mes mains". *Cf.* A. Fourcroy, "Extrait d'une lettre du citoyen ... , au citoyen Van Mons, au sujet de celle de M. Humboldt", *Annales de Chimie*, *22* (1797), 77-80. Antoine Fourcroy was the editor of *La Médecine éclairée par les sciences physique* ... between 1791 and 1792, a journal translated soon afterwards into Spanish with the title *Diario de los nuevos descubrimientos de todas las Ciencias Físicas, que tienen alguna relación con las diferentes partes del arte de curar...* (Madrid: Sancha, 1792), 2 vols. On the medical aspects of the chemical revolution, see F.L. Holmes, The chemical revolution and the art of healing, *Caduceus, 11* (2) (1995), 103-126. On the consequences of this debate in Spain, see J.R. Bertomeu Sánchez; A. García Belmar, Los libros de texto de química destinados a estudiantes de medicina y cirugía en España (1788-1845), *Dynamis*, *20* (2000), pp. 457-489.

[20] Jean-Baptiste-Thimothée Baumès (1756-1828), professor of the Faculty of Medicine of Montpellier, proposed a nosological system based on the new chemistry. His five main classes of diseases were: 'calorinèses' , 'oxigenèses', 'hydrogenèses', 'azotenèses' and 'phosphorenèses'. See J.B.T. Baumès, *Fondements de la science méthodique des maladies, pour servir de suite à l'Essai d'un système chimique de la science de l'homme...* (Montpellier: 1801-1802) vol. I, pp. 174-180. On Baumès, see Holmes , *op. cit.* (19), pp. 118-12

[21] F. Carbonell i Bravo, *De Chemiae ad Medicinam applicationis usu et abusu* (Monspelii: Apud G. Izar et A. Ricard, an IX). On Carbonell, see A. Nieto Galán, *Ciència a Catalunya a l'inici del segle XIX: teoria i aplicacions tècniques a l'escola de Química de Barcelona sota la direcció de Francesc Carbonell i Bravo (1805-1822) (*Barcelona: PhD, 1994). Carbonell published an important textbook on pharmacy and translated several papers

by Fourcroy about the relation between chemistry and pharmacy. Cf. F. Carbonell i Bravo, *Pharmaciae elementa chemiae recentioris fundamentis innixa...* (Barcelona: J.F. Piferrer, 1796) (4th ed. 1824). French translations: Paris, Méquignon l'aîné, 1803; 3rd ed. 1821. Carbonell's translation of Fourcroy's Discourse was published in Madrid by Repullés in 1804.

[22] M.J.B. Orfila, *Elémens de chimie médicale* (Paris: Crochard, 1817) [vol. I, p. ii.]

[23] *ibid.* "cette partie de la science nous ayant paru trop peu avancée pour pouvoir la réduire à des principes généraux".

[24] On these institutions, see M. Astrain Gallart, *Barberos, Cirujanos y Gente de Mar. La sanidad naval y la profesión quirúrgica en la España ilustrada* (Madrid: Ministerio de Defensa, 1996).

[25] The alumni register of Paris Medical Faculty (*Bibliothèque Faculté de Médecine*, Paris, Ms. 25, 131-154) offers evidence that Luzuriaga attended courses by Jean Baptiste Langlois and Jean Louis Marie Solier de la Romillais. At the Collège du Roi, Luzuriaga attended lectures by Joseph Roulin (1708-1784) in 1782 (ACF, A-XIV/8). More information in A. Chinchilla *Anales históricos de la medicina en general y biográfico-bibliográficos de la española en particular* (Valencia: Imprenta de López y Cia., 1841-46), vol. IV, 357-59

[26] *Observations sur la physique...*, *25* (1794), 252-261.

[27] On this point, see J. Riera, "Los estudios en el Reino Unido de Ignacio María Ruiz de Luzuriaga, documentos y epistolario 1785-1787", *Cuadernos de Historia de la Medicina española*, *14* (1975), 269-301.

[28] AHN. *Hacienda*, libro 6463, f. 341, and lib. 6467, f. 296 v.

[29] On the Collège de Girone, see L. Dulieu, *La médecine en Montpellier* (Montpellier: 1986), vol. III (1) pp. 219-226. On Garriga, see A. García Belmar; J.R.Bertomeu Sánchez, "El *Curso de química general aplicada a las artes* (1804-1805) de San Cristóbal y Garriga". In: J.L. Barona Vilar *et al.* (ed.), *Las ciencias en la Ilustración* (Valencia: Universitat de València, 2002) (forthcoming).

[30] C. Meinel, "Theory or practice? The eighteenth century debate on the scientific status of chemistry", *Ambix*, *30* (1983), 121-132.

[31] For an introductory study about the Economic Societies and Sciences, see J. Fernández Pérez, "Las sociedades económicas de Amigos del País". In: M. Selles; J.L. Peset; A. Lafuente (comp.), *Carlos III y la ciencia de la Ilustración* (Madrid: Alianza Editorial, 1988), pp. 129-140. See also the references cited therein.

[32] On this chair, see Gago, R.; I. Pellón *La cátedra de química del Seminario de Bergara* (Bergara, 1994), which includes additional bibliography.

[33] See R. Gago *et al*., "El plan del rector Blasco (1786) y la renovación de las disciplinas científicas en la Universidad de Valencia: la química y la enseñanza clínica", *Estudis*, *6* (1977), 157-170; A. Ten Ros, "La ciencia experimental en la Universidad española de la Ilustración. El laboratorio químico de la Universidad de Valencia: 1787-1807", *Asclepio*, *28* (1985), 287-312; A. García Belmar; J.R. Bertomeu Sánchez, "El laboratorio químico de la Universidad de Valencia a través de sus gastos". In: H. Capel; J.M. López Piñero; J. Pardo (eds.), *Ciencia e Ideología en la ciudad* (València: Generalitat Valenciana, 1992), vol. I, pp. 123-132.

[34] See A.G. Rocasolano, "La escuela Química de Zaragoza", *Universidad*, *13* (1936), 254-287.; I. Aramendia, "La cátedra de química de la Real Sociedad Aragonesa de Amigos del País", *Llull*, *20* (1997), 739-746; P.G. Echeandía, *Función pública de abertura de las cátedras de Botánica y Química, que celebró la Real Sociedad Aragonesa* (Zaragoza: Institución "Fernando el Católico"-Real Sociedad Económica Aragonesa, 1997).

[35] For biographical information about Mateu Orfila, see A. Fayol, *La vie et l'oeuvre d'Orfila* (Paris: Albin Michel, 1930); J. Hernández Mora, Orfila. "El hombre, la vocación, la

obra", *Revista de Mallorca, 49* (1953), 1-121; and S. Loreén, *José Buenaventura Orfila. Estudio crítico-biográfico de su obra e influencia* (Zaragoza: C.S.I.C., 1961). On his chemical research and teaching, see J.R. Bertomeu Sánchez; A. García Belmar, "Mateu Orfila (1787-1853) y las clasificaciones químicas", *Cronos*, *2* (1) (1999), 3-46. and J.R. Bertomeu Sánchez; A. García Belmar, "Mateu Orfila's *Elémens de chimie médicale* and the Debate about the Medical Applications of Chemistry in Early Nineteenth Century France", *Ambix 47* (2000),1-25.

[36] On Ardit and his travels and publications, see A. Nieto Galán, *op. cit.* (21), pp. 189-203 and A. Nieto-Galán, *Coulouring Textiles. A History of Natural Dyestuffs in Industrial Europe* (Dordrecht: Kluwer, 2001), p. 126.

[37] ANF, AJ16, 6426-6428. According to the register, he studied medicine between 1816 and 1820.

[38] ACF*,* Paris, A-XIV/20. He attended Jacques Thenard's lectures during 1818. More data about Desprats in A. Gil Novales, *et al*., *Diccionario biográfico del trienio liberal* (Madrid: Ediciones el Orto, 1991), p. 178.

[39] See M.D. Martínez No, "Les pensions culturals de la Junta de Comerç i la figura de Josep Roura i Estrada (1797-1860)", *Pedralbes. Revista de Historia Moderna*, *8* (2) (1988), 335-347. There is an interesting French police report on the activities of Roura in France during the 1820s. *Cf.* ACF*,* Paris, F7 /12062 (2243). More information about other *pensionados* coming from the Junta de Comerç, see M.S. Oliver, *Los Españoles en la Revolución Francesa* (Madrid-Buenos Aires: Renacimiento, 1914).

[40] See AHN, *Hacienda*, book 6463, f. 103v.; *Ibid*., book 6464, f. 207-207v.; *Ibid.* book 6467, f. 266v.-267; *Ibid.* book 6468, f. 58v.-59 and 599-600.

[41] *Ibid.*, book 10.832, f. 169v.-170, April, 8th, 1791. More information in García Belmar, *op. cit.* (2).

[42] *Bibliothèque Interuniversitaire de Pharmacie*, Paris, register 81.

[43] *Bibliothèque Faculté de Médecine*, Paris, Ms. 25, 131-154.

[44]. Gago, *op cit*. (4), 282-283.

[45] AHN, *libro* 10828, f. 241-242, July 7th, 1787 and book 6463, f. 294, September 28th, 1787. See Gago *op cit*. (4).

[46] "tomar conocimiento de los adelantamientos que ha tenido la química, encargar los instrumentos que no pueden hacerse aquí, y, sobre todo, a instruirse menudamente de lo que se practica en las Casas de la Moneda de París y Bordeaux en lo relativo a fundición, afinación, apartado, métodos de ensayos y refundición de nuestras monedas, procurando adquirir Planos, o modelos de los Hornos y Máquinas más útiles, y un completo conocimiento del mecanismo de las Labores, gastos que ocasionan, precauciones que se observan para evitar desperdicios y mermas y todo lo demás que fuera digno de notar y advertir. *Cf.* AHN, *Hacienda*, book 10828, f. 241-242, July 7th, 1787.

[47] AHN, *Hacienda*, book 6479, f. 230v., May 5th, 1803. On Garriga, see García Belmar, *op. cit.* (29).

[48] "Lettre de Garriga, médecin, etc. Aux redacteurs des Annales de Chimie", *Annales de Chimie, 48* (an XII), 104-107; *La Décade Philosophique, 31*, an XII (4e trim.) (1804), pp. 193-198 and *Journal Général de Médecine*, *XVII*, an XII, pp. 437-446

[49] *Annales de Chimie, 53* (an XIII), pp. 115-118. Other favourable reviews were published in *Décade Philosophique*, an XIII (IIIè trim.), pp. 70-71; an XIV (Ie trim.), pp. 385-387; and *Journal générale de médecine, XXI*, 341-342 ; *XXIV*, 239; 446-451.

[50] *Archives de l'Académie des Sciences de Paris, Mémoire sur les cuves d'indigo par M Garriga, médecin de l'université de Montpellier et pensionné de S.M.C*., Lu le 21 septembre 1807, 36 p. The report of the French chemists was published by L. N. Vauquelin; J.L. Gay-Lussac; C. Berthollet, "Rapport d'un memoire sur les cuves d'indigo de M. Garriga, docteur en

médecine, et pensionnaire du Roi d'Espagne", par MM..., *Annales de Chimie, 65* (1808), 99-106 and *Mémoires presentes a l'Institute des Sciences, lettres et arts, par divers savants, et lus dans ses assemblées. Sciences mathématiques et physiques* (Paris: Baudin, 1811), vol. II, pp. 634-636.

[51] On this project, see García Belmar, *op. cit.* (29).

[52] On this chair, see J.R. Bertomeu Sánchez; A. García Belmar, Pedro Gutiérrez Bueno (1745-1822) y las relaciones entre la química y la farmacia durante el último tercio del siglo XVIII, *61* (2) (2001), pp. 539-562.

[53] Many authors praised Don Antonio's support to science. See P. Gutiérrez Bueno, *Manual del arte de vidriería para uso de los fabricantes de vidrio, cristales, piedras preciosas artificiales y esmaltes*. (Madrid: Villalpando, 1799 and G. Bañares, *Filosofía Farmacéutica* (Madrid: 1814), vol. I, pp. i-ii.

[54]. *Plan de la Escuela práctica de química establecida en Madrid, y aprobado por S.M. en 13 de enero de 1803*, which has been published by X. A. Fraga Vazquez "El Plan de la Real Escuela Práctica de Química de Madrid (1803), una alternativa institucional para la incorporación de la Química en el Estado español", *Llull, 18* (34) (1995), 35-65.

[55]. *Ibid.* "Luego que un Discípulo se halle capaz de desempeñar el empleo de Profesor será nombrado para tal o cual cátedra según la mayor o menor urgencia que haya en las Provincias y enviado inmediatamente a París por espacio de sólo un año, donde verá los Profesores más célebres, notará su modo de enseñar, los establecimientos de Historia natural, de química y mineralogía, etc; acabará de fortificar y perfeccionar sus conocimientos comparando unos con otros los profesores, sus sistemas, escuelas, etc.; y comprará al mismo tiempo, bajo la dirección del Embajador, las obras e instrumentos que sean indispensables para la Escuela que ha de dirigir a su regreso".

[56] On these students, see García Belmar, *op. cit. (2).*

[57] "Recherches sur quelques combinations du mercure; par M. Taboada, élève de Proust", *Journal de Physique, de chimie et d'histoire naturelle, LX* (an XIII), 378-390.

[58] AGS, *Gracia y Justicia*, File 1090. Report by Gabriel Fernández de Taboada, April 18th, 1809. And APR, *Gobierno Intruso*, Book 2209, f. 45 v. (534). More information on Fernández Taboada in R. Roldán Guerrero *Diccionario biográfico y bibliográfico de autores farmacéuticos españoles* (Madrid: Gráficas Valera, 1958-76), vol. II, p. 216; A. Meijide Pardo, *El científico Fernández Taboada (1776-1841)* (A Coruña: Sem. de Estudos Galegos, 1988); Fraga Vázquez, *op. cit.* (54) and R. Sisto Edreira,; X.A. Fraga Vázquez, "A recepcion da ciencia moderna na Universidad de Santiago, 1772-1845. A incorporación da Física e da Química e o labor dos colexios prácticos", *Ingenium*, *5* (1996), 23-58.

[59] AGS, file 1089, Report by the "Real Sociedad Económica de Amigos del País", Zaragoza, May 16th, 1809; AMHN, *Química*, box 001, file 6. *Oposiciones*, May 21th, 1818. More information in M. Tomeo Lacrue *Biografía científica de la Unviversidad de Zaragoza*, Zaragoza, 1962, 113-114 and García Belmar, *op cit.* (2).

[60] See Valera, *op. cit.* (2).

[61]"La experiencia ha acreditado que las dotaciones señaladas para estudiar química en las naciones extranjeras suelen producir un efecto casi siempre muy contrario al que se promete el Gobierno porque al paso que amortiguan el ardor y afición al estudio en aquéllos que las consiguen, creyéndose con bastante derecho para obtener los empleos a menos costa que los demás perjudican por esto mismo las esperanzas de aquéllos que se proponen estudiar de veras". *Cf. Plan de la Escuela práctica ....* In Fraga Vázquez, *op.cit.* (54), 59.

[62] "Relación de los Exercicios literarios, méritos y servicios de D. Pedro Gutiérrez Bueno..." (early nineteenth century). In APR, box 490, exp.26, p.5. See Bertomeu Sánchez, *op. cit.* (52).

[63]. "Sobre el orden que se debe seguir en el fomento de las ciencias naturales y las artes", *Variedades de Ciencias Literaturas y Artes, I,* 1803, pp. 212-226.

[64.]On this point, see J. Riera, *Cirugía española ilustrada y su comunicación con Europa* (Valladolid: Publicaciones, 1976); D. Ferrer, *Historia del Colegio de Cirugía de la Armada de Cádiz* (Cádiz: 1961) and Astrain Gallart, *op. cit.* (24). We are grateful to Mikel Astrain for substantial information about this issue that he kindly offered to us.

[65.]AHN*,* book 6463, f. 202, 14.07.1787. On Aréjula see R. Gago *et al.*, "Juan Manuel de Aréjula (1755-1830) y la introducción en España de la nueva nomenclatura química", *Cuadernos de Historia de la Medicina Española*, *13* (1974), 273-295 and Bertomeu Sánchez, *op. cit.* (19).

[66] On this School see A. Rumeu De Armas, *Ciencia y tecnología en la España Ilustrada. La Escuela de Caminos y Canales* (Madrid: Turner, 1980).

[67.] AHN, *Hacienda*, book 6468, f. 76-76v. See also Palacios Remondo, J. *Los Delhuyar. La Rioja en América. Biografía de los hermanos Juan José y Fausto a través de fuentes y bibliografía* (Logroño: Gobierno de la Rioja, 1993), p. 331.

[68] Letter by Manuel Angulo, Schemnitz, July 4th, 1788. Reprinted in G. Puig y Larraz, Viajes de estudio por Europa..., *Boletín de la Sociedad Geográfica de Madrid*, *40* (1899), 168-169.

[69] On the liberal exiles in Paris, see R. Sánchez Mantero, *op. cit.* (18). On exile in England, see V. Lorens, *op. cit.* (18). On the exile of collaborators with the Napoleonic Government, see P. Barbastro Gil, *Los afrancesados. Primera emigración política del siglo XIX español (1813-1820)* (Alicante: Instituto de Cultura "Juan Gil-Albert", 1993).

[70] See R. Belhoste,." Les caractères généraux de l'enseignement secondaire scientifique de la fin de l'Ancien Régime à la première guerre mondiale", *Histoire de l'Education, 41* (1989), 3-45; N. Hulin, *L'organisation de l'enseignement des sciences* (Paris: Comité des travaux historiques et scientifiques, 1989); C. Fournier-Balpe, *Histoire de l'enseignement de la physique dans l'enseignement secondaire en France au XIXe siècle (*Paris: Université de Paris XI, Thèse de Doctorat, 1994), and M. Gontard, *L'enseignement secondaire en France de la fin de l'Ancien Régime à la loi Falloux, 1750-1850 (*La Calade: Edisud, 1984), About the teaching of chemistry for medical and pharmaceutical students, see bibliography quoted in Bertomeu Sánchez, *op. cit.* (35). On technical, agricultural and military education, see F. B. Artz,. *The development of Technical Education in France, 1500-1850* (Cambridge: University Press, 1966); A. Léon, *Histoire de l'éducation technique* (Paris: PUF, 1968); and T. Charmasson (ed.), *L'enseignement technique de la Révolution à nos jours* (Paris: I.N.R.P. and Economica, 1987). For legal aspects, see A. Beauchamps, *Recueil des lois et règlements de l'enseignement supérieur (1789-1914)* (Paris: Delalain, 1880-1915).

[71] AMCN, *Química*, 001, file 8 (1), Letter by Alcón Calduch, Paris, January 1st, 1820.

[72] A. Fourcy,. *Histoire de la École Polytechnique* (Paris: chez l'auteur, 1828; reprinted in Paris, Belin, 1987); M. Bradley. "Scientific education for a new society: the École Polytechnique, 1795-1830", *History of education, 1* (1976) , 11-24.

[73] R. E. Misas Jiménez "Un químico español del reinado de Fernando VII: José Luis Casaseca y Silván", *Llull*, *19* (36) (1996), 131-160; We are grateful to Dr. Misas Jiménez for his help on this topic. See also García Belmar, *op. cit.* (2).

[74.] He was registered on the courses of Jean Baptiste Langlois y Jean Louis Marie Solier de la Romillais at the Faculty of Medicine (*Bibliothèque Faculté de Médecine*, Paris (Ms. 25, 131-154)), as well as on the courses given by Joseph Roulin (1708-1784) at *Collège de France* in 1782 (ACF*,* Paris (A-XIV/8)). According to Chinchilla, he studied with Macquer, Fourcroy , Antoine-Laurent Jussieu (1748-1836) and Louis Jean Marie Daubenton (1716-1800), as well as various teachers from the *École de Chirurgie* of Paris (Chinchilla, *op. cit.* (26)*,* vol. IV, pp. 357-59).

[75] ANF, Paris, AJ16, files 6422-6430.

[76] See J.R. Bertomeu Sánchez; A. García Belmar, "Alumnos españoles en los curso de química del *Collège de France* (1774-1833)". In: *Actes de les III Trobades d'Història de la Ciència i de la Técnica als Països Catalans* (Barcelona: SCHCT, 1995), pp. 407-418.

[77] ANF, AJ16/1915. and *http://www. lamarck.net*, where he is registered on the courses for 1815.

[78] Orfila described his first lectures in his autobiography published by M.G. Chapel D'Espinasoux, "La Jeunesse d'Orfila. Fragment d'une autobiographie inedite publié par ...", *Revue Hebdomadaire*, *22-3* (1914), 615-34; 86-113.

[79] Letter from Mateu Orfila to his mother, Paris, February 16th 1812. Printed in M.C. Bosch, "Contribució a l'epistolari d'Orfila", *Randa*, *30* (1988), 133-176.

[80] Orfila's autobiography reproduced by M.G. Chapel D'Espinasoux, *op. cit.* (78). See also Orfila's letter to *Junta de Comerç* of Barcelona, Paris, November 29th, 1814 in *Arxiu de la Biblioteca de Catalunya,* Barcelona*, Junta de Comerç*, 21 bis 366.

[81] The letters were printed by P. Lemay, "Contribution à la biographie d'Orfila", *Bull. Soc. Franç. Hist. Med.*, *25* (1931), 516-22.

[82] Orfila, *Elémens de chimie médical, op. cit.*(22)*,* vol. I, p. II. Orfila's autobiography in Chapel d'Espinasoux, *op. cit.* (78). The *Athénée* of Paris replaced the Musée created by Jean-François Pilâtre of Rozier (1757-1785) in Paris, where important chemists such as Lavoisier, Fourcroy, Brogniart, Thenard, Chevreul, etc. gave classes. By mid-century, when Orfila wrote his autobiography, the institution no longer had the prestige it had enjoyed in the years when he gave his first chemistry courses. See C. Dejob, *De l'établissement connu sous le nom de Lycée et d'Athénée et de quelques établissements analogues* (Paris: Colin, 1889) and W.A. Smeaton, "The early years of the Lycée and the Lycée des Arts", *Annals of Sciences*, *11* (1955), 309-19; 349-55.

[83] Arxiu de la Biblioteca de Catalunya, *Junta de Comerç,* 21 bis 263, Letter by Carlos Ardit, Paris, November 25th, 1814.

[84] *Decade Philosophique*, *7* (an VII), pp. 443-444.

[85] *Annales de Chimie*, *34* (an VIII), p. 103. Quoted by J. Simon, *The Alchemy of Identity. Pharmacy and the Chemical Revolution, 1777-1809 (*University of Pittsburgh: Ph.D. 1997), p. 190.

[86] J.P. Maygrier, *Guide de l'étudiant en médecine...* (Paris: Gabon, 1818). pp. 41-42 and p. 197.

[87] L. Hubert, *Almanach général de médecine pour la ville de Paris. 1827. Par ..., chef des bureaux de la Faculté, secrétaire du Jury médical* (Paris: Gabon et Cie, 1827), pp. 144-146.

[88] Cf. *Rapport de M. Orfila sur l'état de l'enseignement médical en France*, September 10th, 1837 in A. Beauchamps, *Recueil des lois et règlements de l'enseignement supérieur (1789-1914)* (Paris: Delalain, 1880-1915), vol. III, pp. 612-652. See Bertomeu Sánchez, *op. cit.* (35).

[89] J.H. Warner, *Against the Spirit of System* (Princenton: University Press, 1998), chap. III.

[90] Gaulthier translated W. Henry's textbook into French during these years and he also played a minor role in the transmission of Daltonian atomism in France. See A.J. Rocke , *Chemical Atomism in the Nineteenth Century. From Dalton to Cannizzaro* (Ohio State University Press: 1984), p. 69 and M.P. Crosland (1968), "The First Reception of Dalton's Atomic Theory in France". In: D.S.L. Cardwell (ed.), *John Dalton and the Progress of Science* (Manchester: Univ. Press, 1968), pp. 280-281.

[91] AMCN, *Química*, 001, file 4 (4), Antonio Benito, París, January 20th, 1816. On Benito's collaboration with José Napoleón I, see Mercader Riba, J. *José Bonaparte, Rey de España* (Madrid: CSIC, 1983), pp. 88-89.

[92] *Ibid. Química*, 001, file 7 (6). Report activities by Andrés Alcón, Paris, October 26th, 1819.

[93] It has been already mentioned that Alcón greatly valued his acceptance at the École Polytechnique: "[It is] so remarkable taking into account that I am the only foreigner [...] who has been allowed to enter the school". Cf. AMCN, Madrid, *Química*, 001, file 7 (6) Report by Andrés Alcón, Paris, January 1st, 1820.

[94] *Ibid.*

[95] AMCN, *Química*, 001, file 7 (1). "con el objeto de instruirse más de propósito en la práctica de la tintorería, e introducir en España, por medio de un curso público las perfeccionadas maniobras de este arte importante, y difundir los principios científicos en que se fundan". On this case see F.J. Puerto Sarmiento. "La huella de Proust: el laboratorio de química del Museo de Historia Natural", *Asclepio*, *46* (1) (1994), 197-220, and García Belmar, *op. cit*. (2) and (29).

[96] *Ibid.*, Report by José María de San Cristóbal, Louviers, February 20th, 1820.

[97] *Ibid.*, Report by José María de San Cristóbal, Paris, April 18th, 1820.

[98] "Viajar de una parte a otra, [...] averiguar de antemano los nombres de los principales propietarios de manufacturas, [...] buscar para ellos algunas recomendaciones que las más veces son inútiles, de gastar mucho tiempo en ganar la confianza de los más accesibles, antes de penetrar en el santuario, digámoslo así, de las artes y conferir con sus ministros; a todo lo cual se agregan todas las trabas [que suponían el escaso valor de su pensión de 1000 reales mensuales que debían servir] "para viajar [...] gratificar operarios y lo que es sobremanera útil o para decirlo con más verdad, del todo necesario hacer ajustes con los maestros que le dejen a uno ver, preguntar y hacer libremente, sin cuya condición es imposible lograr el objeto propuesto" (*Ibid.*, *Química* 001, carpeta 7 (1), Report by San Cristóbal to the Spanish Government, Paris, May 12th , 1820).

[99] AHN, *Estado*, file 5327 (23). Report by J.M. San Cristóbal, París, November 22th, 1824. The book was published by Vitalis in 1810 and was reissued. See Nieto-Galán, *op. cit.* (36) and García Belmar, *op. cit.* (29).

[100] *Ibid*. Quoted from a letter written by Marqués de Casa-Irujo, November 4th,1821.

[101] *Ibid.* Letter by Marqués de Casa-Irujo, Paris, May 25th, 1822, reporting about a letter from San Cristóbal.

[102] He was requested to send reports written by well known French monarchic notables but, even if he succeeded in obtaining these letters, his return to Spain probably never took place. See García Belmar, *op. cit.* (27).

[103] " Avant que la chimie eût ramené à des principes généraux les nombreuses opérations de l'industrie, les fabriques, les manufactures, étaient, pour ainsi dire, l'apanage de quelques nations et la propriété d'un petit nombre d'individus; le secret le plus absolu couvrait chaque procédé du voile du mystère; les formules et les pratiques se transmettaient en héritage de génération à génération. La chimie a tout dévoilé: elle a rendu le domaine des arts le patrimoine de tous; et, en peu de temps, on a vu tous les peuples, chez lesquels cette science a été cultivée, s'enrichir des établissements de leurs voisins. Les préparations de plomb, de cuivre, de mercure; les travaux sur le fer; la fabrication des acides; l'apprêt des étoffes; l'impression des couleurs sur toile; la composition des cristaux, des terres cuites et des porcelaines, etc.; tout cela a été tiré du secret, et forme aujourd'hui une propriété commune" Cf. J.A.C. Chaptal *Chimie appliquée aux arts* (Paris: Déterville, 1807), vol. I, xv, and vol. III, 5-7, about the role of the war in this process.

[104] L.N. Vauquelin; J.L. Gay-Lussac; C. Berthollet (1808), *op. cit.* (50) on p. 100. See García Belmar, *op. cit.* (27) for more information.

[105] E. Maffei; R. Rúa Figueroa, *Apuntes para una Biblioteca española de libros, folletos y artículos, impresos y manuscritos, relativos al conocimiento de las riquezas minerales y a las*

ciencias auxiliares (Madrid: 1871-72), vol. I, p. 495; Gago, *op. cit.* (32), pp. 21 and 54. Many Portuguese "estrangeirados" also belonged to the Freemasons. See A. Carneiro; A. Simoes; M.P. Diogo, "Enlightenment Science in Portugal: the *Estrangeirados* and their communication networks"**,** *Social Studies of Science, 30* (4) (2000), 591-619; M. P. Diogo; A. Carneiro; A. Simoes, "The Portuguese naturalist Correia da Serra (1751-1823) and his impact on early nineteenth-century botany", *Journal of the History of Biology*, *34* (2) (2001), 353-393.

[106] J.R. Harris, *Industrial Espionage and Technology Transfer. Britain and France in the Eighteenth Century* (Aldershot: Ashgate, 1998), pp. 435-6.

[107] A.J. Barreiro, *El Museo Nacional de Ciencias Naturales* (Madrid: Museo de Ciencias Naturales, 1992) (1st ed. 1944), pp. 71-72 and Harris, *op. cit.* (106), p. 435, who mentioned "M. Angelo". Angulo collaborated with Guyton de Morveau and, in 1786, was appointed vice-director of the Royal Cabinet with the order of teaching chemistry. He was also appointed Director of Mines at the end of 1786. *Cf.* AHN, *Hacienda*, book 10827, f. 495v., December 28th, 1786

[108] Harris, *op. cit.* (106), pp. 436-347.

[109] *Ibid.* pp. 208 and 309. According to Palacios Redondo, Le Camus was a member of the Basque Society Cf. Palacios Remondo, *op. cit.* (67), p. 133).

[110] AMCN, *Química*, 001, several letters addressed at Izquierdo, 1786-1788.

[111] A. Muriel, *Historia del Reinado de Carlos IV*. In: *Biblioteca de Autores Españoles*, vol. 115, p. 42-43. G. Puig y Larraz, "Viajes de estudio por Europa (Francia, Austria, Alemania central, Prussia, Holanda, Suecia, Noruega e Inglaterra) durante los años 1788-1795: cartas científicofamiliares de Manuel de Angulo...", *Boletín de la Sociedad Geográfica de Madrid*, *22-24* (40-42) (1898-99), pp. 154-155. More information about Izquierdo's activities in the correspondence published by I. Pellón; P. Román, *La Bascongada y el Ministerio de Marina. Espionaje, Ciencia y Tecnología en Bergara (1777-1783)* (Bergara: Real Soc. Bascongada, 1999).

[112] The full text of both sets of instructions is reproduced in Palacios Remondo, op. cit. (67), 128-132.

[113] Palacios Remondo, *op.cit.* (67), 131.

[114] Elhuyar attended Bergman's lectures in 1782 and took some notes in French, which have been published by A. Fredga; S. Ryden, "Juan José de Elhuyars anteckningar efter Toberbn Bergmans föreläsningar 1782", *Lychnos*, *11* (1959), 161-208. We are grateful to Dr. Anders Lundgren for his help on this question.

[115] On Elhuyar's trip see A.P. Whitaker, "The Elhuyar mining missions and the Enlightenment", *Hispanic American Historical Review*, *31* (4) (1951), 557-585; Palacios Remondo, *op. cit.* (67), 112-11 and Gago, *op.cit* (32)., pp. 25-32. For other "metallurgical travellers", see Harris, *op. cit.* (106), pp. 222-237, notably pp. 233-235 on the Carron ironworks.