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THE RESEARCH SCHOOL OF CHEMISTRY OF ADOLPHE WURTZ, PARIS, 1853-1884

by

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ABSTRACT

Adolphe Wurtz (1817-1884), established a research school of chemistry in the Faculty of Medicine in Paris, which developed throughout the second half of the 19th century, acquiring an international reputation. Owing to particular circumstances, which relate both to his Alsatian background and his internationalist ethos, Wurtz's school exhibited certain peculiarities which were in contrast with the current practice of the French scientific establishment and, in particular, with that of other leaders of research schools in Paris. In order to study this research group, a framework of analysis has been constructed, taking into account the origin of the school as a means of organising scientific research, and trying to understand its full meaning in the French context of the time. Thus, a brief account of the research schools of chemistry in Paris contemporary with that of Wurtz is given: the schools of Cahours, Sainte-Claire Deville, Pasteur and Berthelot .

A detailed account of Wurtz's school of chemistry is then given, focussing on three major aspects: 1) Wurtz's personal, cultural and educational background, his ideology as well as his career both as a chemist and as a member of the Parisian scientific establishment; 2) his students in particular, their identification and national origins, their cultural and educational backgrounds, their interests, their involvement in Wurtz's school, the research areas and the publishing and institutional activities in which they took part, their publications and their careers; 3) finally, an analysis of the full meaning of the school: the research laboratory, its peculiar administration and routine; a comprehensive analysis of the foundations and development of both the theoretical and empirical aspects of Wurtz's research programme, especially in organic and biological chemistry, as well as the contributions of his students to the programme; an account of the activities in a wider context, focussing on scientific and educational institutions and publications, which were either launched, controlled or supported by Wurtz's school.

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Abbreviations

Ann. Chim.- *Annales de Chimie.*

Ann.Sci.- *Annals of Science.*

Ass Fr.Av.Sc.C.R.- *Comptes Rendus de l'Association Française pour l'Avancement des Sciences.*

B.J.H.S.- *British Journal for the History of Science.*

Ber. dsch. Chem.Ges.- *Berichte der deutschen Chemischen Gesellschaft.*

Bull. Soc.Chim Fr.- *Bulletin de la Société Chimique de France.*

Bull.Soc.Ind. Mulh.- *Bulletin de la Société Industrielle de Mulhouse.*

C.R.- *Comptes Rendus Hébdomadaires des Séances de l'Académie des Sciences, Paris.*

D.S.B.- *Dictionary of Scientific Biography.*

Hist.Sci.- *History of Science.*

Hist.Stud.Phys.Sci.- *Historical Studies in the Physical Sciences.*

Journ.Chem.Educ.- *Journal of Chemical Education.*

Journ.Chem.Soc.- *The Quarterly Journal of the Chemical Society of London.*

Journ.Frank.Inst.- *Journal of the Franklin Institute.*

Journ.Soc.Chem.Ind.- *Journal of the Society of Chemical Industry.*

L'Ann Sci.Ind.- *L'Année Scientifique et Industrielle.*

Lieb. Ann.= Ann.Chem.Pharm.- *Liebig Annalen = Annalen der Chemie und Pharmacie.*

Monit. Sci.- *Moniteur Scientifique.*

Phil.Mag.- *Philosophical Magazine.*

Proc.Am.Phil.Soc.- *Proceedings of the American Philosophical Society.*

Proc.Roy.Soc.- *Proceedings of the Royal Society of London.*

Proc.Roy.Soc.Edin.- *Proceedings of the Royal Society of Edinburgh.*

Rép.Chim. Pur.- *Répértoire de Chimie Pure.*

Rev.Gén.Sci.Pur.App.- *Revue Générale des Sciences Pures et Appliquées.*

Rev.Quest.Sci.- *Revue des Questions Scientifiques.*

Rev.Sci.- *Revue Scientifique.*

Stud.Rom.- *Studies in Romanticism.*

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INTRODUCTION.

> At a time when England, Prussia, the German states and Russia make the greatest effort to provide their respective university teaching with an unusual luxury, certainly you, the Minister, would not like the Faculty of Sciences to remain at the back of this noble movement of the human spirit. (Jean- Baptiste DUMAS, 1840)[1]

> It is longtime since Mr. Liebig gathered in Giessen students coming from all countries of the world and founded a justly famous school, and the study of chemistry greatly developed in Germany. Large laboratories were built at Giessen, Heidelberg, Breslau, Göttingen, Karlsruhe and Greifswald. Science profited and Germany was rightly proud and is now doubling its effort in order to raise the teaching of practical chemistry to a high standard, in accordance with modern requirements. (Adolphe WURTZ, 1864)[2]

Modern historians and sociologists of science have been increasingly interested in focussing their attention on small groups of scientists and their interactions. However, the ways in which they have approached the subject have been substantially different. According to Geison[3], sociologists have been concerned with emerging specialties and networks of communication, and historians more with research schools. The historical work carried out on research schools is still in its early stages, but from the literature available some generalisations and systematisation of criteria have been attempted. While they do not claim to have constructed universal models, Geison , Morrell[4] and Klosterman[5] have made important contributions in this respect. Thus, Geison provided a definition of a research school in the following terms:

> Small groups of mature scientists pursuing a reasonably coherent programme of research side-by-side with advanced students in the same institutional context engaging in direct, continuous social and intellectual interaction.[6]

On the other hand Morrell, in his article on the respective research schools of chemistry of Liebig and Thomas Thomson, established some categories for the analysis of research schools within his "conjectural model of an ideal research school"[7]. The criteria provided by Morrell were systematised and applied by Klosterman in his study of J. B. Dumas's research school. Klosterman approached this group in terms of Dumas's leadership role, the laboratories, the research students (identification, social interactions, careers, professional relationships, etc.) and the research programme.

Although these attempts at a generalisation and systematisation of criteria are invaluable, they also raise some questions, especially with regard to their applicability. Part of the problem resides in the temptation to make a particular case or situation fit into these kinds of ideal models, leaving out features or characteristics which were intrinsic to the case under consideration. From my point of view, these models should not impose constraints on historical analysis: rather, they should be accepted as flexible guiding principles. Moreover, the above studies seem also to have largely ignored the cultural framework which made possible the emergence of research schools as a particular case inscribed in a more general context.

Research schools emerged as a typical creation of the19th century, and particularly as a product of a context which was generated from the Romantic Movement and German Naturphilosophie. The school was thus the Romantic model for the transmission of knowledge and of particular methods of research, which, however, were not restricted to scientific knowledge. Science was integrated in a holistic philosophical approach embodying fields like history, poetry and music. After all, the school was a form of perpetuating in time and through the coming generations what was thought of as valid and truthful, in the context of that heightened historical awareness[8], which itself emerged from Romanticism.

The emergence of schools of chemistry in France cannot be fully understood without considering the Romantic context and without taking into account the cultural interactions between German and French intellectuals and savants during the 19th century. In particular the interactions between German Romanticism, Naturphilosophie and what was to become the French Positivism should be recognised. During the Second Empire, when it is commonly assumed that Positivism largely dominated the French scene, the translation of the German Romantics and Naturphilosophen such as Schelling, Fichte, Hegel, Herder, Kant, Goethe, Hölderlin, and others reached a peak. Especially between the mid 1830s and the late 1860s not only was their work translated and published but also histories of German philosophy and critical analyses were produced in journals like Revue des deux mondes, Revue de l'instruction publique, Revue germanique, Revue critique, Revue chrétienne and Revue de Strasbourg[9].

1- The Romantic context.

Romanticism has usually been ignored and dismissed by history of science[10] mainly due to the positivistic context in which this discipline was established as a field of research[11]. As a consequence of the status of objectivity ascribed to science especially by scientism[12] which developed from Positivism, Romanticism was (and still is) often identified with pure metaphysics, mysticism and mere speculation, and accordingly it is thought to have been almost irrelevant to the "progress of real science". Within this tradition Romanticism was usually seen as a matter more appropriate for research in philosophy, literature, or art, and its implications in scientific production or research organisation are usually underestimated, not to say ignored. Among the reasons for this is the prejudice that Romanticism is too loose as a concept, but in fact it is no more not less so then the Enlightenment or the Renaissance and as an international movement it is undeniable that it presented unity, despite its complexity[13]. In addition, the qualification of loose seems to deny the very nature of Romanticism, whose unity consisted precisely of an attempt to resolve a particular set of oppositions and contradictions[14]. Of course, unity does not mean uniformity and it is unreasonable to expect that each of its characteristics must be found in each of those involved, whether philosophers, writers, scientists or artists are considered. As a non-organised movement Romanticism spread during the 19th century in Europe and in America, and far from being confined to philosophy, literature and art it affected, in my view deeply, the course of an enormous range of fields such as social thought, historiography[15], science and scientific organisation.

After dealing with the historical sources under analysis in this thesis I was led to consider that the relations between Romanticism and science may possibly be looked at differently. This means that instead of restricting the study of these interactions to the analysis of pieces of research in physics, chemistry or any other science which, having been carried out on a purely speculative basis may have contributed decisively to the "progress of science", we should perhaps be seeking answers to other kinds of questions. This means that instead of providing a history of solutions and achievements, if we choose a historical approach based on the history of problems raised in a particular historical period[16], we may start to ask questions as for instance: What kind of problems were introduced by Romanticism and Naturphilosophie? In particular, what kind of world view was made available by the Romantics and Naturphilosophen? What happened to these problems and to this world view in the course of the 19th century? Were experiments and empirical practices outside the scope of the Naturphilosophen? If Romanticism and Naturphilosophie were reactions to the Enlightenment and its egalitarianism based on rationality as expressed in the motto of the French Revolution Liberté, Egalité Fraternité, was not French Positivism and more especially that of Auguste Comte reacting against the same? Is it possible that Romanticism already had the "germ" from which a more radical empiricism could develop? Were Romantics and Positivists so completely apart? Why were the German universities from the early 19th century onwards so committed to the development of schools and of research and why the French savants, despite their often extreme empiricism, were constantly invoking them as a model to be followed by French universities? Is it possible to conceive that Romanticism and Positivism may have been the two sides of the same coin? Is it plausible to conceive that the 19th century had been the Romantic Age[17] to the extent that during this historical period responses were made to the questions raised by the Romantic Movement, and that the different and often contradictory solutions which were given were scattered around the main lines of a model of thought generated by it?

The aim of this thesis is not to provide answers for all these questions. However in the course of this research they appeared to be relevant for the subject under consideration. As a reaction to the Enlightenment, with both its uniformity justified by reason and its potential agnosticism, the Romantic Movement and Naturphilosophie initiated in the late 18th century made available a new attitude in relation to the world, which for the purposes of this thesis may be briefly summarised in three points: the Romantic organic universe; the location of research at the centre of university teaching and scholarship; the religious crisis and Positivism.

The world view made available by the Romantic Movement and Naturphilosophie was to have various implications in various sciences and branches of knowledge which, in my view, were to be impressed on the scientific production of the whole century. Thus, the (Newtonian) mechanical universe, which had dominated the 18th century, was replaced by an organic and dynamic universe: nature was seen as an enormous living organism. The model of a unified cosmos was no longer the model of Newtonian physics, but that of an organism in which each part had a relation to the whole[18]. The emphasis was thus placed in the study of inner forces and inner structures, instead of mathematical or purely experimental descriptions of external phenomena which, in the previous century, had been obtained by reducing nature to various isolated mechanisms. The key concepts of organism and organisation were to dominate several fields of knowledge and more specifically were to lead to the emergence of such a concept as biology[19], which was itself paradigmatic of an approach emphasising relations rather than isolated objects. The world was apprehended in a temporal dimension, in which opposed polarities interacted to produce changes at an internal level, whether in the realm of the organic, the inorganic or the spiritual. Science was not seen as isolated, but as one of the various elements of an integrated knowledge which included languages, poetry, music, religion, social knowledge,history, etc..

Naturphilosophie, however, did not deny science and experiments[20], but its essence was rather phenomenalism. The associated epistemology of this unified view of knowledge in which all branches were related, was mainly based on a theory of analogy and on a genealogical method which had inherently a strong historical dimension. Consequently, the studies produced in various areas were to reveal striking methodological similarities[21]. Associated with the Romantic Movement and its world view, a new historical consciousness was consequently introduced, which permeated the discourse produced whether in literature, philosophy, history, or science, throughout the 19th century. This historical dimension dominated the studies on geology, on animals and plants, on geographical regions, on languages, on chemistry and on physics, which were to emphasise dynamic aspects and to reflect the tensions between what remained unchangeable and what changed during processes developing in time. As a consequence, classificatory systems were also to be put forward but, unlike those of the 18th century which were based on the assessment of external features, these were founded upon analogies and relations inferred from abstract representations of internal structures.

Thus, without a consideration of these trends made available by the Romantic Movement and Naturphilosophie, both the replacement of animal and vegetable chemistry in the 18th century by organic chemistry in the 19th century and the emergence of classificatory systems of organic compounds based on the establishment of genealogies would be difficult to understand. Among these classifications that of Gerhardt was to become the framework of the scientific programme implemented by Wurtz's school. Gerhardt used a genealogical method and classified chemical compounds into four abstract types, which had been formulated from analogies derived from a comparative study of chemical reactions. His type theory was to imply the development of a chemical atomic theory, and the Positivistic reactions against it from chemists like Berthelot and Deville become clearer if we consider Positivism as an alternative response in a Romantic Age.

As far as the organisation of research was concerned, the emergence of schools was, from the ideological point of view, closely associated with the models of university education whose terms and formulation constituted one of the novelties introduced by Romantics and Naturphilosophen. These located research in the centre of university teaching and scholarship, and the formulation of the principles underlying the establishment of schools were made available by Naturphilosophen like Schelling, Fichte and Schleiermacher[22]. Notably the publication of Vorlesung über die Method des Akademischen Studiums in 1803 by Schelling was to lead to a reform in German universities in which the von Humboldt brothers were to play a major role. Schelling advocated that the aim of the university was the pursuit of truth in the context of a holistic concept of knowledge (Wissenschaft). He also argued that the role of a university teacher was not to transmit facts, since these could be learnt in encyclopedias and the like, but to initiate students in the methods of pursuing the truth, i.e., the methods involved in research and criticism[23]. As a consequence, the teacher was represented as someone who produced scholarly research work, and both learning and teaching must have no limitations of any kind, Lern-und Lehrfreiheit. With the assumption that knowledge was almost an endless pursuit of truth combined with the idea of freedom of teaching and learning, some of the principles for bringing research to the focus of attention in German universities were provided. This spirit was reinforced by a revival of Medieval practices, so dear to many Romantics, in which the guilds and the medieval universitas, provided an inspiration both for the teacher, as a Meister giving guidance to original discovery, and the student as an apprentice[24] within a

Bildung[25] process. These ideals had also been presented in contemporary literature, which had helped their propagation through works like Goethe's Wilhelm Meisters Lehrjahre (1795-1796) and Novalis's, Die Lehrlinge zu Sai (1802)[26].

In addition, in 1805 Fichte was also to contribute to the philosophy of this reform claiming that universities should produce instead of reproduce knowledge, and the results of these pursuits should be publicised. Accordingly the universities should have their own journals to channel the results of investigation. In this context, Fichte mainly focused on the role of the scholar ascribing him with the greatest importance by emphasising his education and his role both as an educator and most especially as a creative person[27]. As regards students, he advocated that they should not be confined to the universities in which they were educated but they should travel and attend others, in order to widen their horizons, to avoid nationalism and to develop an international perspective.

Also in the early century Schleiermacher, by criticising the bureaucratic and centralised model implemented by Napoleon I in French higher education, suggested an alternative which stressed a cooperative relationship between teacher and student, involving collaboration in mutual respect and individual freedom[28]. Even by the turn of the century, when research became increasingly more institutionalised and specialised in Germany, these ideals and what remained from them, were still highly praised by German men of science contemporary to Wurtz, like Helmholtz[29]. Although adopting a more empirical view of scientific research and criticising several aspects of Romanticism and Naturphilosophie, Helmholtz retained many facets of it , particularly, the ideal of a "scientific artist", similar to that advocated by Fichte[30], and the search for holistic principles underlying nature. He thus lectured on the union of physics, physiology, psychology and aesthetics[31] and criticised the French universities, arguing that they were tied to rigid programmes. In his opinion these programmes only presented the subjects completely understood and established on a steady basis, leaving aside debatable and uncertain questions. In addition, he argued that French universities did not take into account the capacity for discovery of both students and teachers: the former were taught to succeed in demanding exams, the latter were only required to possess accumulated knowledge[32].

The Romantic Movement and Naturphilosophie, therefore, were to generate the ideological principles for the emergence and justification of schools and as regards chemistry, notably that of Liebig. Liebig established within the University at Giessen a school of chemistry which was to become a paradigm for further research schools of chemistry throughout Europe. Despite Liebig's formal rejection of Naturphilosophie and adoption of an empirical approach to chemistry[33], the basis of which he acquired during his research training in France with Gay-Lussac, he was to retain in the organisation of his research school many of the features advocated by the Naturphilosophen for a reform of the German Universities[34]. In particular, research training was a part of education; emphasis on publishing research, which materialised in the control of a journal by his school; emphasis on the individual, since pupils published under their own names, assuming full responsibility for their investigations; cooperation among pupils inside the laboratory; a cosmopolitan facet illustrated by the various nationalities of his students[35]. These were also to be features of Wurtz's school.

The German ideals of university teaching, research and scholarship, were constantly invoked by the French chemists throughout the 19th century as a model to follow. However, it acquired specific features, which affected not only Wurtz's school, but even more its Parisian contemporaries. The particular features of the French schools of chemistry were associated with France's recent history, culture, philosophical debates and organisational practices, to which was added the German example in a mixture of both fascination and also revulsion, expressed especially after the Franco-Prussian war[36].

However, among the most influential debates of the mid century, which also affected the organisation of schools in France, especially by providing models of behaviour, was the perceived conflict between science and religion: the recent origins, again, seem to be in the Romantic Movement. As Schenk put it:

> One of the leitmotivs of Romanticism was the simultaneous existence of and dissonance between the two keynotes: namely the quest for religion and the inability to embrace it.[37]

This religious quest did not affect merely those more immediately associated with the Romantic Movement, who claimed, like Novalis, that:

> There is not yet a religion. It is necessary to found a school of true religion. [38]

Savants, in particular, were apparently far from being immune to these religious and mystical matters. However, while throughout the century many returned to the religion in which they have been brought up usually after a period of "malady of soul"[39], others found alternatives like Buddhism (Charcot), Spiritualism (Butlerov and Richet) or strict Positivism, itself seen as a substitute for religion. In fact, Comte's Religion of Humanity had been modelled on Catholicism[40] and the aim of creating an Eglise Positiviste may be seen as a response to agnosticism through the generation of a new religion based on science. This would ensure stability, social "order and progress". If many Romantic features from the early century can be found in Comte[41], by the mid century in France, when theologians and philosophers were especially under attack particularly from Positivism, a notorious positivist like Renan (a close friend of Berthelot), while referring to the influence on him of both German Romantic philosophy and scholarship, claimed that:

> It was this that I was looking for, the conciliation of a highly religious spirit with a critical spirit.[42]

As a hierarchical philosophical system constructed also for the prevention of egalitarianism, personal turbulence and social upheavals, Positivism was thus to lead to specialism in science and to advocate strict and centralised forms of control, which affected scientific organisation. Throughout the 19th century Positivism, despite its strong metaphysical dimension, was to advocate as a principle, the rejection of both religion and metaphysics. The Positivists claimed that the only valid scientific approach should be an empirical one. These factors, i.e., the religious dimension ascribed to science as a replacement for religion, extreme empiricism, and rigid forms of control were to become strong features of French schools of chemistry, both as regards their organisation, their scientific production and their ideology. Wurtz's school, however, in its ideology, its organisational practices and its chemical research was closer to Naturphilosophie and the German models of scholarship than to the French. As it will be seen in due course, the reasons for this difference can be related to Wurtz's Alsatian background, in particular, with his education in the Gymnasium of Strasbourg, with the ethics associated with his Lutheran religious beliefs and with his contacts with German universities. The study of this distinct background, which within the French context provided Wurtz with the possibility of adopting a different ethos and a peculiar position over chemical theory can certainly illuminate the controversy on atoms, which took place in the Académie des Sciences as late as 1877, opposing Wurtz to Berthelot.

Throughout this thesis the issues briefly discussed above will gradually emerge. To dismiss the interactive context of Romanticism and Naturphilosophie with French culture, and particularly Positivism, would reduce the historical focus of this thesis to such an extent that, an aseptic account of the school of chemistry of Adolphe Wurtz in the context of those of his French contemporaries would probably result, as a cimetière en ordre[43]. I do not intend to make claims about the direct influence of Romanticism in the research schools of chemistry of the second half of the 19th century. Nonetheless, it seems that a certain group of ideas usually taken as Romantic is present in the French cultural context of that period. Although symptoms of its existence can be detected particularly in Wurtz's school, the exact extent and importance of such ideas cannot be determined for sure at the level of this study. Further research on this subject would allow more definitive claims to be made.

In addition, the French solution for the introduction of research in institutions for higher education revealed several specific features, which raised methodological problems that could not be resolved satisfactorily by merely adopting the frameworks of analysis used in previous studies. Consequently, an attempt was made to establish an adequate methodology for the analysis of Wurtz's research school of chemistry and its contemporaries in the cultural context of the time.

2- Methodology.

Although presented in advance, the framework for the study of Wurtz's research school emerged in reality a posteriori and was derived from the study of the corresponding 19th century sources. As a starting point, the very useful criteria provided by Klosterman were adopted inasmuch as they had been applied to a French research school of chemistry of the mid-19th century. However, some problems arose from the strict adherence to these criteria, particularly with regard to the consideration of Wurtz's research students. Wurtz's laboratory was mentioned in several sources[44] as having been attended by more than one hundred research students (élèves), whose names were provided. Although commonly described in the French sources as élèves, an analysis of each case revealed that their status inside the school varied. Thus, four different categories may be distinguished:

a) those who, following Wurtz's research programme, carried out research and published research papers;

b) those who attended the laboratory but never published research papers, during the time spent there, but adopted the theoretical views of the research programme, which are visible in later publications;

c) those not so closely involved in research, who only followed the general principles and ideology of the group and collaborated in some of its activities in a wider context;

d) those who combined these features.

The criteria applied by Klosterman are not sufficient to account for all these categories and for this reason he was led to include Pasteur among Dumas's research students even though Pasteur never carried out research in his laboratory. Pasteur was a follower of Dumas in many respects, and the latter acted as his patron throughout his life. To this extent Klosterman cannot be accused of inaccuracy. He based his inclusion of Pasteur in Dumas's school on the following facts: Pasteur attended Dumas's lectures at the Sorbonne and called him maître[45]. But the problem is, however of a different nature. The notion of élève does not coincide exactly with the notion of research student and the word maître has a special meaning in the French context. Thus, to make this question clear it is absolutely necessary to determine the exact meanings of the French words élève and maître contextually.

From the analysis of the sources, one of the most striking points is that like their German colleagues also the French leading chemists of the mid-19th century presented the school as the ideal form of organisation of chemical research and deliberately tried to build up research groups in the universities. This led to the establishment of a basic infrastructure of chemical research, but unlike their German counterparts, they had no formal link with the higher education institutions where they were located. They only depended on the individual initiative of their respective leaders, notably Cahours, Deville, Pasteur, Wurtz and Berthelot. As evidence, the examples of Cahours at the Ecole Polytechnique and Deville at the Ecole Normale may be taken. When Cahours was appointed to succeed Regnault in 1851 at the Ecole Polytechnique, the space that Regnault had been given had never been used for chemical research[46]. With Deville there was a similar situation when he replaced Balard, whose laboratory at the Ecole Normale had served as a store room[47]. In addition these research schools were never referred to by the name of the institution in which they were set up, but always by the name of their respective director. Furthermore, research laboratories were not funded by the government. If official funds for research were obtained, this was due to personal influence. For instance, Deville's laboratory at the Ecole Normale was later considered the only adequate research laboratory existing in Paris, but this was due partly to his contact with the Emperor[48]. Only an annual sum amounting to a maximum of 1,800fr., was respectively available to higher educational institutions for laboratory expenses. Nevertheless, this amount was intended exclusively for teaching purposes such as demonstrations for their ordinary undergraduates. In order to carry out research, the most these chemists could expect was the general sympathy of the administration[49].

Given this picture, we may begin to ask some questions: What was meant by a research school in France in the mid-19th century? What was meant and what was expected from a director or leader of a research school? What did it mean to be a research student?

It is worth studying the language used. The designation of école de recherche (research school) was never used, but instead only the word école (school). Secondly, the chefs d'école (leaders or directors) were addressed always as maître (master), and finally the élèves were never called élèves de recherches (research students), but simply élèves (pupils), denoting as it will be seen throughout this thesis, several Romantic connotations[50].

Since Geison's definition of research school and Klosterman's criteria are unable to account satisfactorily for these distinct designations, a precise definition of these terms is required. These definitions are not clear if the above terms are merely translated by the nearest English equivalent to the French term. For this reason an examination of the full meaning of the French words is necessary, at the particular time they were being used. To make this task easier I used the multi-volume Nouveau Larousse Illustré (1898-1907) because it summarises the cultural meanings, which became apparent to me from a wide range of documents. Thus, under the word maître the following meanings are given:

- someone who commands, governs at will people or things.
- someone to whom esteem and respect are given.
- someone who has a superior skill or knowledge.
- someone who provides an example to follow (to consider someone as one's master).

Associated with the word maître is the expression avoir de bon maître, meaning to be under the protection of a powerful person[51].

On the other hand, the word élève is defined as follows:

- someone who receives lessons from another.
- someone who attends the courses at an educational institution.
- an artist who is educated by the lessons and example of another.
- someone or something that owes one's (its) way of being to another person considered as a master.[52]

But , the term élève also has a more extended meaning:

> The young man as an educated person, formed in his morals or in the practice of an art, at the same time as he receives theoretical instruction.[53]

This meaning is equivalent to that of the French word disciple, which is much broader than the English word disciple:

> It means not only one who receives lessons from a maître, but also someone who adopts his doctrines and ideas and tries to walk following the same path.[54]

Finally, the word école was given as:

> a group of adherents of a maître or of a philosophical, artistic, or literary, etc. doctrine.[55]

Associated with the word école is the expression Faire école, meaning:

> to gather around one's ideas (système) a great number of imitators

or adepts. (une idée qui fait école).[56]

Taking into account all these meanings, to restrict the analysis of the écoles to the terms of Geison's definition of research school and to the criteria provided by Morrell would be misleading. Instead, in the present study, the école will be brought to play the central role, and consequently the maître and the élève, according to the terms as they were understood in this particular period in France.

The concept of école permeated the whole French cultural context of the 19th century. Thus, it applied to a variety of fields ranging from a particular artistic, literary or musical style (école impressioniste or école wagnérienne), to a philosophical (école positiviste), scientific approach or theory (école équivalentiste or école atomiste). In all these cases, the école was primarily a paradigm for the transmission of ideas, morals, theories, methods and practices (the système)[57], implying either the adoption of a style, an approach, a theory, or the imitation of the maître, including his posture inside and outside the école. The maître could be assumed either as a person advocating a système or could be reduced to the système itself. But, whenever a practical component was intrinsically present in the système as in chemistry, the imitation of the maître naturally encapsulated apprenticeship. This explains why often the écoles of chemistry were, in a Romantic fashion, compared to those of the fine arts. In fact, in both cases the performance of actions involving work with one's hands was implied. But, in the écoles, these actions were necessarily transcended because they had to be subordinated to a système, i.e., at least to an aesthetic ideal or to a chemical theory. Because of the absence of a système Frémy's school for technical training at the Muséum was not considered by the chemical community of the time as belonging to the leading group of écoles of chemistry in Paris. The training provided was considered elementary because Frémy rejected theories of any kind to frame laboratory procedures, which led him to claim that he only aimed at training préparateurs[58]. However, many of those who attended laboratories considered as écoles were often also to become préparateurs after their research training. But if the ideas or doctrines which framed the set of practices in question were indispensable to qualify an école as such in France, they also helped to define its identity. As regards the écoles of chemistry, the système personified in the maître consisted of his laboratory practices, i.e., his chemical research, his theories and ideology, which therefore integrated not only a perspective of doing science, but also of the role of the savant in a wider context. Indeed the roles of savant and that of the maître as a chef de école were largely seen by the chemical community as a service to public welfare[59].

In the context of the mid-19th century France, the écoles of chemistry had undoubtedly a particular prominence, which perhaps cannot be compared with any other science. In fact, these écoles were particularly coherent and sophisticated in their forms of organisation, which does not seem to have occurred to the same extent in other sciences. However, at least one example should be mentioned: that of Regnault in physics. Regnault had been trained by Liebig, but later moved to physics and established an école at the Collège de France. His laboratory was attended by several French and foreign young savants[60], notably William Thomson (Lord Kelvin), who not only received research training, but also absorbed some of Regnault's views on doing science[61]. Among the several reasons that may explain the prominence of the écoles of chemistry, we may point out both the type of arguments that chemists had at their disposal, and especially their positions and power in the French scientific and political scene. The type of arguments that were brought in to obtain support for the official establishment of écoles played a major role and from this point of view the French context was more favourable to chemists than to other savants. On the one hand the process for a wider implementation of écoles was launched during the Second Empire when Napoleon III was particularly committed to develop industry, and chemistry had traditionally more impact on French industry[62] than physics, for instance. Thus, an economic argument was available and was often reinforced by science-based German industry, which was presented as a fine example. On the other, another strong argument was, however, of a different nature and was epitomised in the figure of Lavoisier. In fact, he became an invaluable instrument for propaganda by being transformed into a symbol of French scientific genius. The large number of publications devoted to Lavoisier[63] during the period covering the Second Empire and the Third Republic show how much his symbolic power was used, and Wurtz himself was to claim that chemistry was a French science in the introduction of his Dictionnaire de chimie pure et appliquée (1869).

Besides these arguments, other more influential factors played a decisive part at a practical level. One was the tradition inaugurated by Liebig followed by Dumas with their groups of chemical research, which were often invoked as models. The other was surely Dumas's powerful position in the French scene, mainly due to his administrative and political appointments, especially during the Second Empire. He clearly favoured and was able to protect in a singular way the establishment of the écoles of chemistry at the institutions for higher education in Paris and, excepting one (Berthelot's), they were run by four of his former students and were, in one way or another, ran under his patronage. As a result a network of écoles was built up in Paris.

Thus, if the école was primarily a model of training embodying the transmission of a système, in the case of chemistry, at least, it also implied in practice a form of organisation and a definition of roles and status. Thus, patronage was intrinsically associated with the status of maître, determining the type of relations existing among the various maîtres and also the relations between the maîtres and the élèves. Therefore, in the chemical scene at the top of the system a large amount of power and authority was concentrated in Dumas's hands[64], justifying the ironic epithet l'Etre suprême coined by Dr. Quesneville, editor of the Moniteur scientifique[65]. Part of this power in turn was distributed to these leading chemists gravitating around him - Cahours, Deville, Pasteur, Wurtz, Berthelot, who were engaged in the direction of their respective écoles. For, if on the one hand Dumas played the role of patron of these leading chemists, on the other, each of them was the patron of his respective élèves. Indeed this network of maîtres and their respective élèves constituted the fundamental basis of the macro-organisation of the chemical community in Paris in the mid 19th century.

In turn the status of élève implied not only laboratory training, but also adhesion to the underlying système. Thus, the identity of the école was significantly based on a common position regarding chemical theory and on the ideological principles shared by its members. In fact, the écoles found their place and acquired their meaning within a framework of values widely accepted by the chemical community, which also extended to the political and administrative sphere. As an example of how the transmission of these values was clearly intended, Dumas's eulogy of Deville should be mentioned, particularly when he referred to the ideal chef d'école :

> The situation of a chef d'école, if one is dealing with fine arts or with an experimental science, must not be considered as a position in which surrounding oneself with intelligent, hard-working élèves and assisting them with advice drawn from benevolent experience is sufficient. Things do not happen that way. The head of a laboratory or studio must give an example of complete devotion to his task, must be patient, work with his hands, be the first to arrive and the last to leave. The élèves must be proud of their maître; discoveries must be seen, new ideas set in motion or masterpieces applauded, attracting the attention of the intellectual world or man of taste to this école. Under such an influence, devotion to duty is strengthened, imaginations grow excited, generations animated with the same spirit, move forward together towards the conquest of truth in science or of beauty in art. Only by paying this price does one found an école, is one a maître, a beloved maître if to the gifts of intelligence, giving confidence and respect, are added a sovereign goodness of heart, the ineffable source of affection[66].

But, this same type of argument was later incorporated in political discourse, in such a way that the écoles were presented as a kind of national ideal. Thus, Liard, Director of Higher Education in the Ministry of Instruction , invoked in the late 19th century the examples provided by the German universities and by several French écoles of chemistry[67], to claim that the écoles should be the basis underlying organisation of higher education.

> In its highest sense the word Ecole is a set of doctrines, which links various investigations and on which achievements are based...whenever the genius of outstanding studies bears fruit, a university atmosphere emerges. I mean by that a set of ideas, moral tastes and principles, which is transmitted from parents to sons.[68]

However, while in the German Romantic concept of school and university the Meister was supposed only to provide the methods for his apprentices to find their own solutions in the process of seeking the truth, after all an assisted form of Bildung as it had been claimed by the Naturphilosophen and reinforced by several works of literature in the early century, in the context of French scientific establishment of the mid-century the situation was different. The maître was supposed to transmit a unilateral scientific method and what was already established as the truth. Therefore the élèves were a means of perpetuating theories, values, and postures in order to ensure an orderly progress from which , as it was claimed, society was to benefit.

Moreover, both the diffusion of values explicit in Liard's words and the theoretical position together with the laboratory practices advocated by the école were carried out through a model of organisation, whose description was epitomised in the family metaphor in which the maître played the role of a father. In fact, with such an organisation, the perpetuation of the status-quo and its associated patronage was also envisaged. Providing that the authority of the maître was strengthened by a fatherly posture, the system could hardly be contested insofar as he was, by definition, committed to do his best for his protégés. In addition, although in much more practical terms J.M. Crafts[69] would say that a scientific career in France would be impossible without membership of one of these groups, or without the protection of a maître:

> The influence of individuals and of schools upon patronage of the younger men for educational positions is peculiarly important in France. The destiny of a student of science depends greatly upon the leader whom he chooses to follow, and there is sufficient cohesion among the members of a school to make it an effective body.[70]

As a matter of fact, both the definitions found in the Larousse and all these examples provide evidence for us to realise to what extent the école was framed in ideological principles, which had some of his roots in the German model but also incorporated Positivistic ideology. Through the appropriation of Christian moral values Positivism had meanwhile tried to convert science into a moralising activity and a model of rationality. Thus, despite their religious differences, it is not surprising that both positivists and Catholic chefs d'école were represented in a similar manner, notably through the usage of the "apostle" metaphor [71], since many values were shared at a moral level:

> Sciences introduced in the entire social body the philosophical or scientific spirit, this scrutinising spirit which submits everything to a severe reason, condemns ignorance, dispelling prejudices and errors. They raise intellectual standards and moral feelings.[72]

Particularly, in the chemical community[73], this ideology consisted of a set of values related to a certain concept of science and savant, which defined an ideal framework for organisation and behaviour. At the same time, they provided arguments, which were invoked whenever these chemists claimed funds and better facilities, but above all to justify their aims and power.

Taking into account the above considerations, the framework which is going to be applied in this study was defined by focussing on three major categories: the maître, the élèves and the école. Since the French écoles were strongly personalized, the figure of the maître was consequently strongly emphasised, acquiring a symbolic dimension. Besides his paternalistic role the maître was converted into a moral symbol, by associating moral values with his person.[74]

> May his [Deville's] example develop among young people who engage in a scientific career, since devotion to science is one of the most elevated, humble and pure forms of expressing love to the Motherland.[75]

The maître is to be approached as the figure who transmitted his views on chemical theory, his procedures and techniques, his ideology, and above all provided the example that the élèves were supposed to follow. Thus his social and cultural background, the research which gained him recognition, his personal characteristics, morals and tastes, the ways in which he exerted his power inside and outside the école and how he assumed his role as a patron are to be analysed.

The élèves will be considered as those who were expected to imitate the maître. Besides, their origin, background, their interests and their involvement in the current research and activities of the école in a wider context, their professional posts while élèves and their careers after leaving the école are to be studied.

Finally, the école is to be considered both in its internal and external dimensions. In its internal dimension the école embodied a locus and a système. The locus was the research laboratory in its multiple aspects: the physical aspect and institution setting, its budget, administration, organisation, routine and day-to-day atmosphere. The système is to be studied as a set of chemical theories, ideas, principles, morals and practices. The external dimension of the école is to be approached through the analysis of its interactions with the outside world, notably publication, engagement in organisations and institutions as well as in its political and administrative involvement, which was itself a typical French practice.

The écoles of chemistry existing in Paris in the period under consideration are not yet studied as such, although biographies devoted to some of their respective maîtres are available. A general account of these groups will be given, however, in order to provide a better understanding of Wurtz's école in its context. To begin the sketch of the coexisting groups, our attention will be focussed on Cahour's école, in the first place, followed by the others in chronological order.

NOTES TO INTRODUCTION.

1- Translated from quotation given in PAUL, H.W., The sorcerer's apprentice. The French scientist's image of German science, 1840-1919, (Gainesville, 1972), p.5.

2- Wurtz to the Minister of Public Instruction (10 December 1864). Paris, Archives Nationales, F17 4020. Also quoted in Paul, op.cit. (1), p.7.

3- GEISON, G.L., "Scientific change, emerging specialties, and research schools", Hist.Sci., 19 (1981), 20-40.

4- MORRELL, J.B., "The chemist breeders: the research schools of Liebig and Thomas Thomson", Ambix, 9 (1972), 1-46.

5- KLOSTERMAN, L.J., "A research school of chemistry in the nineteenth century: Jean Baptiste Dumas and his research students", Ann.Sci., 42 (1985), 1-40 (Part I); 40-80 (Part II).

6- Geison, op.cit. (3), 23.

7- Morrell, op.cit. (4), 3-7.

8 As Schenk pointed out the Romantic attitude to the past should be envisaged as a "tendency to use history as a substitute to religion" and achieve immortality. See See SCHENK, H.G., The mind of European romantics., (London, 1966), p.45. See also MOTZKIN, G., "The Catholic Response to secularisation and the rise of the history of science as a discipline", Sci. Cont., 2 (1989), 203-226.

9- See CHARLTON, D.G., Positivist thought in France during the Second Empire, 1852-1870, (Oxford, 1959).

10- For instance, in the recently published book CUNNINGHAM, A., JARDINE, N. (edit.), Romanticism and the sciences (Cambridge, 1991) it was pointed out that since 1941 there has been no general work on the relations between Romanticism and the Sciences. Also LOW, R. "The progress of organic chemistry during the period of German Naturphilosophie (1795-1925)", Ambix, 27 (1980)1-10, makes a remark on the disqualifications of Romanticism in history of science.

11 See Motzkin, op.cit. (8), 203-226.

12- See chapter "From positivism to scientism", in Charlton, op.cit.(9), 86-126.

13- See Schenk, op.cit. (8), p.XXI (preface).

14- See Schenk, op.cit. (8), p.XXII (preface).

15 With the Romantic Movement, historiography became concerned not only with what had been achieved and said in the past, but especially with what had been thought. These were, for instance, the views of L. von Ranke (1830) and F.W. Maitland by the turn of the 19th century. As Renan and Nietzsche remarked this historiography was a creation of the 19th century. In addition a new sense of the past resulted from archaeology and from the emerging pre-history investigations, with which chemistry was to become involved, notably through Berthelot. See Schenk, op.cit.(8), p.41-42 and BERTHELOT, M., Archéologie et histoire des sciences, (Paris 1906).

16- RABINOW, P., (edit.), The Foucault reader. An introduction to Foucault's thought, (London 1984), p.343.

17- Romantic Age is the term used by JAMESON, F. The prison-house of language. A critical account of structuralism and Russian formalism, (Princeton, 1972), p.4, in a way similar to that which Michel Foucault coined as Age Classique to designate the 18th century épistémè. See FOUCAULT, M. Les mots et les choses, (Paris, 1966). For Jameson Romantic Age is not restricted to the Romantic Movement, but refers to the historical period (19th century), in which an organic model permeated the discourse in several domains of knowledge, see p.VI (preface).

18- SNELDERS, H., "Romanticism and Naturphilosophie and the Inorganic natural sciences, 1797-1840: an introductory survey", Stud.Rom., 9 (1970), 193-215. Also WETZELS, W.D., "Aspects of Natural Science in German Romanticism" Stud Rom., 10 (1917), 44-45.

19- See JACOB, F., The logic of life. A history of heredity, (London, 1989), p.87.

20- KNIGHT, M., "German science in the Romantic period", in CROSLAND, M.P., (edit.), The emergence of science in Western Europe, (London, 1975), p.163.

21- For instance, both in comparative anatomy, from which the concept of biology had been derived almost simultaneously by Lamarck, Oken and Treviranus, and in chemistry, which Dumas symptomatically called chimie comparé, new approaches emerged based on the establishment of basic prototypes (Urtyp, as for Goethe) from which the differences between organs and molecules, were respectively explained by metamorphoses undergone by those basic types. See chapt. 4 of this thesis. Similar patterns were used in other fields of knowledge like philology and comparative literature. If from the 18th century Grammar had emerged as a static system of rules for languages from the Romantic Movement emerged philology, i.e., the reconstruction of proto-languages and the establishment of families of languages based on their inner-relations. Schlegel, Diez, Rask, the brothers Grimm and Bopp developed respectively the studies on Indian-, Romance-Germanic- and Celtic- related languages. See Schenk, op.cit.(8), p.41-43.and Jameson, op.cit. (17), p.4.

22- SHAFFER, E.S., "Romantic philosophy and the organization of the disciplines: the founding of the Humboldt University", in Cunningham; Jardine, op.cit. (10), p.38-54.

23- See FARRAR. W., "Science and the German university system, 1790-1850" in Crosland, op.cit.(20), p.179 192.

24 Ibid.

25 It means self-cultivation, a tradition highly praised by the Germans. See BRUFORD, W., The German tradition of self cultivation. 'Bildung' from Humboldt to Thomas Mann, (Cambridge, 1975).

26- See NOVALIS (F. von Hardenberg), Les disciples à Saïs et les Fragments de Novalis (transl.), (Brussels, 1914); CARDINAL, R., German romantics in context, (London, 1975), p.15 and 33; Bruford, op.cit. (25),p.29-30. For instance Novalis in his work Die Lehrlinge zu Sai , describes a wise old master having his pupils collecting leaves and stones, experiencing how to enquire the analogies in Nature. The master is represented as someone who knows how to perceive analogies and connexions in Nature.

27- See Shaffer, op.cit.(22), p.45.

28 Ibid., p.47.

29 See HELMHOLTZ, H., "La liberté académique dans les universités allemandes" Rev.Sci., 14 (1878), 813-820.

30- Shaffer, op.cit. (22), p.46.

31 As Turner put it:

> Helmholtz belonged to that brilliant and self-concious generation of German scientists which arose in open reaction to the scientific Romanticism of earlier decades. Yet- far more than they cared to admit- Helmholtz and his generation still harbored many of the preconceptions and even the program of the earlier science. Like many of his Romantic predecessors, Helmholtz devoted his life seeking the great unifying principles underlying nature.

See TURNER, R.S., Article Helmholtz, D.S.B., vol.6, p.241-253 (252).

32 See Helmholtz, op.cit. (29).

33- However, Low, op.cit.(10), 5, showed how Liebig incorporated in his both organic and agricultural chemistry arguments made available by Naturphilosophie.

34- See Shaffer, op.cit. (10), p. 38-54 and Farrar, op.cit. (23), 179-192..

35- See Morrell, op.cit. (4) and FRUTON, J. "The Liebig research group- a reappraisal". Proc. Am. Phil. Soc., 132 (1988), 1 66

36- See Paul, op.cit. (1) and COLEMAN, W., (edit.), French views of German science, (N. York, 1981).

37- Schenk, op.cit. (8), p.76.

38- See Novalis, op.cit. (26), p.156.

39- Meaning Weltschmerz or maladie du siècle, i.e., a feeling or belief dominated by nothingness.

40- COMTE, A., The positive philosophy, (transl.), (N.York, 1974), p.IX (preface). See also Charlton, op.cit. (9).

41- See Schenk, op.cit. (8),p. 45.

42 Quoted from Charlton, op.cit. (9),p.89.

43- Expression borrowed from the French writer A. Musset.

44- These sources are basically: Wurtz's obituary written by his student and follower Friedel; obituaries written by members of Wurtz's group about former colleagues in Wurtz's laboratory; Wurtz's private correspondence. Exact sources to be given later on.

45 See Klosterman, op.cit. (5), 16, 18, 33 and 38.

46 See Ecole Polytechnique, livre du centenaire (1794-1894), (Paris, 1895).

47- See Ecole Normale Supérieure. Livre du centenaire, 1795-1895, (Paris,1896). Also DUMAS, J.B., Discours et éloges académiques, (Paris, 1885), vol.2, p.309.

48 As Liard mentioned:

> Dans tout Paris il n'y a guère qu'un bon laboratoire, celui de Sainte-Claire Deville, à l'Ecole normale, créé et doté par la liberalité personnelle de l'Empereur.

LIARD, L., L'enseignement supérieure en France, 1789-1893, (Paris, 1894), vol.2, p. 273.
A similar opinion was expressed by Wurtz. See WURTZ, A., Les hautes études pratiques dans les universités allemandes, (Paris,1870), p.12.

49- See Liard, op.cit. (48), p.274; GERNEZ in op.cit., (47), p.413, and VALLERY-RADOT, (edit.), Œuvres de Pasteur, (Paris, 1922 1939), vol.7, p.203.

50- See Chapt.3 of this thesis.

51- Nouveau Larousse Illustré, (Paris, 1898-1907), vol.5, p. 858-859.

52- Op.cit. (51), vol.4, p.110.

53- Op.cit. (51), vol.3, p.754.

54 Ibid.

55- Op.cit. (51), vol.5, p.36.

56 Ibid.

57- By système was meant :

> Réunion de principes coordonés de façon à former un tout scientifique ou un corps de doctrine.

See op.cit., (51), vol. 7, p.886.

58- See FREMY, E., Encyclopédie chimique, (Paris, 1881), vol. 2, p.779 and COPAUX, H., (edit.), Cinquante années de sciences appliqués à l'industrie, 1882-1932, (Paris, 1932), p.11.

59- By savant was meant the one who possessed not only extended knowledge, whose supreme form was science, but also skills and erudition. In addition "les savants sont les bienfaiteurs de l'humanité". See op.cit. (51), vol.7, p.564. For instance Gernez mentioned referring to Deville:

> Il Deville comprennait tout ce qu'il aurait d'avantageux pour le bien public à placer des jeunes gens que tente la recherche de l'inconnu dans les conditions ou leur activité scientifique put se développer le mieux.

Gernez in op.cit. (47), p.417.

60- According to Dumas's testimony, Regnault

> Entouré de jeunes maîtres heureux de se voir associés à ses recherches, il se animait de son ardeur des savants français: MM. Bertin, Reiset, Jamin, Izarn, Descos et des professeurs étrangers: Soret, Bede, Blaserne, Lubinoff, Pfaundler et Sir William Thomson, l'illustre physicien écossais.

Dumas, op.cit. (47), p.178.

61- See SMITH, C.; WISE, N., Energy and empire. A biographical study of Lord Kelvin, (Cambridge, 1989), p.107 108.

62-See SMITH, J.G., The origins and early development of the heavy chemical industry in France , (Oxford, 1979).

63- Thus, Dumas published Lavoisier's Œuvres under the Emperor auspices; Berthelot published Lavoisier's laboratory notebook, Grimaux, one Wurtz's most devoted élèves wrote several articles on Lavoisier and a biography.

64- In the enormous Dumas's correspondence in the Académie des Sciences, a considerable number of letters provide evidence for patronage. These leading chemists and their respective élèves, particularly, addressed several letters to Dumas, ranging from private matters to questions relating appointments for official posts. Also letters from ministers notifying Dumas about the nomination, upon his suggestion, of some of these chemist to public posts, are available. Among others the case of Wurtz's appointment for the Committee of Public Hygiene (Paris, Archives de l'Académie des Sciences, Dossier Wurtz).

65 See FIGUIER, L. "Nécrologie scientifique. Dr. Quesneville", L'Ann. Sci. Ind., 33 (1899), 609-610.

66- See Dumas, op.cit. (47), p.307-308.

67- Liard often invoked the examples coming from groups of chemical research, notably those directed by Deville, Pasteur, Berthelot and Wurtz to justify his views and claims concerning the reform of the French teaching system for higher education, which implied the establishment of a general network of écoles:

> Faute de cette organisation, que de forces vives s'étaient perdues en France... Et dans le domaine indéfini des sciences experimentales, que de travaux apparaissaient comme ne pouvant se faire que par la coordination des efforts, par la collaboration des maîtres et de ses compagnons.

Op.cit. (48), p.353.

68- Ibid. p.284. His italics.

69 Crafts had been an élève of Wurtz.

70- CRAFTS, J.M., "Friedel memorial lecture", Journ.Chem. Soc., 72 (1900), 893 1101 (993).

71- See Chapter 1, p. 39 and p. 50.

72- Pasteur, in op.cit. (49), p.216.

73- Owing to the centralised system of French science, I assumed that French chemistry was mainly represented by the Parisian chemists already mentioned. Mention should be made, however, of other chemists who were in the provinces and, among those, the names of Laurent and Gerhardt should be included. Owing to lack of facilities and other various constraints, as maîtres they were reduced to their chemical theories, which found in Wurtz a follower.

74- For instance Pasteur converted his maître Dumas in a model of courage and good citizenship and in a letter he addressed to his grand-son in 1886, he advised him to read Dumas's biography:

> Quand tu auras grandi, puisse la lecture de la glorieuse vie de M. J.-B. Dumas enflammer ton courage et faire de toi un grand citoyen.

VALLERY-RADOT, (edit.), Correspondance de Pasteur, (Paris, 1951), vol.4, p.122.

75- Gernez, op.cit. (47), p.407.

CHAPTER 1- THE ECOLES OF CHEMISTRY IN PARIS IN THE MID-19TH CENTURY.

1- Auguste Cahours (1813-1891) and his école.

1.1 - The maître: his career and public image.

Auguste Cahours was born in a modest family of craftsmen, and in the words of his élève and biographer Etard, while a young man he completely engaged in a lifestyle, portrayed as

> the passionate and generous youth inclined to great ideas in which many of the most eminent spirits of this period were formed[1].

He then entered the Ecole Polytechnique, from which he graduated in 1835, but he abandoned the military life in 1836. As he was attracted by the Romantic école of literature[2] he devoted himself to poetry, writing two volumes which remained unpublished. After this type of experience, common to several savants of the time[3], he entered Chevreul's laboratory at the Muséum as préparateur where he stayed for five years doing what he considered endless tedious routine work[4]. However, he then managed to move to Dumas's private laboratory[5], where he was initiated in chemical research and established friendly relationships, notably with Sainte-Claire Deville and Wurtz.

Cahours's reputation as a research chemist began at a time in which the isolation of organic compounds in natural products constituted one of the main lines for research among organic chemists, and in these circumstances the discovery of a new compound was extremely valued. While at Dumas's laboratory therefore he obtained recognition and saw his scientific credentials affirmed among his peers when he engaged in investigations of potato oil (1839-1840), which led him to the discovery of a new alcohol that he christened amyl alcohol. It was in relation to this work that Dumas made the comment[6] that the discovery of a new alcohol was equivalent to the discovery of a new metal in mineral chemistry and this type of recognition was a fundamental pre-requisite for anyone wishing to have Dumas's patronage. In the next year, Cahours was to work with his Alsatian friend Gerhardt[7], also a former élève of Dumas, on cumin essence,which contributed to knowledge of the aromatic series. These experiments encouraged Cahours to commit himself to the study of essences, namely oil of wintergreen essence and the study of the salicylic series, whose results were highly regarded at the time[8]. Before establishing his école Cahours also carried out research which was to have some impact on chemical theory. Particularly his investigations on abnormal vapour densities had implications for the development of Gerhardt's type theory[9]. From his studies on the vapour density of phosphorus chloride (1845) Cahours was led to produce derivatives of benzoic acid through its reaction with chlorine. With this investigation he provided a general method for obtaining acid chlorides, which allowed Gerhardt to obtain acid anhydrides, giving him a powerful argument to support his type theory.

After attending the private laboratory of the influential Dumas, Cahours was appointed professor of chemistry at the Ecole Polytechnique, replacing Regnault (1851). Here he did not find an encouraging situation, since he had no laboratory facilities for research and the normal courses on chemistry had low prestige. His predecessor had apparently repeated for years the same subjects, simply reproducing what was written in the text book he had published for the students, and so far no chemical research had been carried out at the Ecole Polytechnique.

Cahours's professional career within the French establishment was to develop under Dumas's auspices, since at the time Dumas was clearly the one who controlled the pieces of the chessboard of the chemical posts in higher education. Thus, following the usual pattern characterised by the schemes of cumul[10] and suppléance[11] as forms of promotion and control, Cahours became professor at the Ecole des Arts et Manufactures (1852), succeeding Dumas, and his suppléant at the Sorbonne (1851-1853). When he left this post to be appointed to the Mint (1853-1881) where he replaced Laurent[12], Cahours was succeeded at the Sorbonne by Deville, Dumas's favourite élève. Not withstanding the intrinsic prestige associated with a professorship at the Ecole Polytechnique (1851-1881), Cahours saw both his influence in the academic community and his own capacity for patronage increased with his election to the Académie des Sciences (1868) in the place of Dumas in the chemistry section, when the latter was elected lifelong secretary of that institution.

Cahours was to be portrayed by his élèves and friends as a maître of a humble and quiet disposition but with a deep and subtle sense of humour, a feature which is absent from the representations of several of his colleagues. He was also described as a chemist who liked his friends and élèves to share his views and participate in his work[13]. The atmosphere of his research laboratory was described by Etard as pleasant and lively and these characteristics were also often absent from the descriptions of the laboratories of some of Cahours's contemporaries:

> The young chemists like me and Demarçay who in 1875 had the good fortune and honour of working in his laboratory, did not know the silence du cabinet. We chatted about everything...In those conversations the enthusiasm he transmitted to his élèves about recent developments in chemistry manifested a rare liberalism.[14]

In addition, Cahours was described as a father-like[15] figure and was often suggestively called père Cahours by some of his élèves with whom he maintained a friendly relationship which was not confined to the laboratory. Thus, according to the testimony of Olivier, editor of the Revue générale des sciences pures et appliquées, he gathered for a weekly dinner at his house a group which included his élèves:

> Every Saturday we had dinner chez patron, more often with Grimaux, Léauté, the old Bréguet always amusing, with Gal , who played the modest role of the satisfied savant. Also the astronomer Faye, General Perrier...the historian Rousset, the industrialist Japy and Charcot...In this charming atmosphere, anecdotes, appreciation of men and things, but also current facts of science and various ideas were put forward. The most interesting of those underwent further discussion[16]

This practice is said to have extended throughout Cahours's life. Also Etard and Demarçay, who were described as having had a son-like relationship with their maître, were permanent participants in those social gatherings.

1.2.-The élèves

Cahours established his research laboratory at the Ecole Polytechnique but no official budget was given to fund research, i.e., there were no official funds available either to pay researchers or cover the costs of reagents and apparatus. He therefore recruited his élèves by making use of the junior teaching posts associated with laboratory lectures at the Ecole Polytechnique. Although the symbolic status of this grande école within the French administration, which was enhanced by its military purposes may have imposed limitations, all that can be said is that Cahours, deliberately or not, remained within the constraints imposed by the official teaching system. Therefore, as far as the recruitment of élèves was concerned, the quantity of élèves he trained in chemical research was small, and I only know of Riche[17], Jolyet[18], Pélissard[19], Gal[20], Demarçay[21] and Etard[22]. They all had been recruited either as répétiteurs or préparateurs - posts which themselves did not imply research, but merely teaching. This suggests that, given the circumstances, their appointment had been basically subordinated to their own wish of engaging in a research career. In addition, there is no evidence of foreigners in Cahours's research laboratory. From the group of élèves mentioned above those who acquired more prestige in the French scientific community were Riche, Demarçay and Etard. Yet, as it will be seen later on[23], their careers also show to what extent the écoles of Cahours and Wurtz overlapped in many respects, particularly regarding chemical theory, personnel and patronage.

Like his maître, Riche devoted the greatest part of his youth to literature and writing, and his first steps in chemistry were merely due to an occasional post in a laboratory of the Ecole des Arts et Manufactures, in the course of an economic crisis in his family. After completing his education in science at his own expenses, he was appointed Wurtz's préparateur at the Institut Nationale Agronomique, when this was founded in 1850[24]. As this institution closed two years later for political reasons, Wurtz recommended Riche to Dumas, who appointed him préparateur at the Sorbonne (1853). Here he became friendly with Cahours, Dumas's suppléant at the time. Cahours invited Riche to work in his laboratory at the Ecole Polytechnique, where the latter was appointed répétiteur in 1860. Following the nomination of Cahours to the Mint, Riche was also appointed essayeur to that institution (1862), under the patronage of his maître. Despite poor laboratory facilities he later was to develop his personal research, which was devoted to metallic alloys, during the 45 years he worked at the Mint.

After Jolyet, Pélissard and Gal, Demarçay entered Cahours's laboratory as préparateur in 1875, after having graduated from the Ecole Polytechnique. Demarçay, who was considered as a man possessing a wide culture, soon left his teaching duties to commit himself entirely to research and later he was to work in his own private laboratory. Finally Etard, who after having received elementary training in chemistry from Frémy at the Muséum, was appointed préparateur to Cahours at the Ecole Polytechnique in 1872. However to progress in a scientific career as Etard wished, he had to go through the several stages of a formal education, which he did not possess, since he had spent his youth in South America, where his father had the post of official gardener for the president of Chile. Only after 1875, did he engage in chemical research in Cahours's laboratory. Later he became préparateur of biological chemistry at the Faculty of Medicine, whose director was Wurtz's élève Armand Gautier, and in 1900 he was appointed director of research on biological chemistry at the Institut Pasteur.

Especially Riche, Demarçay and Etard presented some features which are to be found also in the élèves of Wurtz, as it will be seen in due course[25]. Those either possessed economic wealth, as in the case of Demarçay, or other intellectual interests than science related to literature and art, as in the cases of Demarçay, Riche, Etard and of Cahours himself. Like the majority of Wurtz's élèves Demarçay was, in the Romantic fashion, to travel in several countries like Egypt, India and Northern Africa, devoting to his interests in Natural History and philology of oriental languages, leaving for some time his teaching duties at the Ecole Polytechnique. Also Etard, who was interested in foreign languages, particularly cultivated scientific relations abroad, especially with British men of science. He travelled and spent some time in the laboratories of Ramsay, Roscoe and Perkins, because he liked what he considered to be the British theoretical eclecticism and its practical sense. He also cultivated studies on philosophy and history of science, which were not confined to chemistry.

1.3. The école

As regards the système advocated by Cahours, in general terms it reveals itself as ambivalent in relation to chemical theory. In fact, Cahours framed his research in terms of atoms. However, in his personal papers he did not present chemical formulae written accordingly, but rather based on equivalents[26]. In addition , he advised his élèves to advocate atomic theory, which they did. As Etard was to comment about the position of his maître

> In spite of writing formulae according to equivalents, he advised his young friends to adopt atomic theory in their work and notes to be presented in the Académie. He smiled and invoked his age as a reason for not changing.[27]

However, his reasons may have been of a different kind, suggesting that Cahours himself did not dare to challenge directly the established authorities, especially those figures like Dumas to whom he was linked by loyalty. Particularly, if we take into account Cahours 's friendship with Gerhardt, the fate of the latter may have had the effect of preventing him from manifesting openly his own thoughts. Gerhardt in association with Laurent had adopted a controversial posture towards Dumas regarding chemical theory, which contributed to relegating them to posts in the provinces [28]. This may explain Cahours's attitude, which is hinted from Grimaux's comment

> His excessive modesty and lack of daring to build up theories, put his invaluable research in an unjust shade...Cahours's spirit was not inclined towards theoretical conceptions or bold generalisations, which characterise the reformers. Very shy, owing to the respect in which he held his own maîtres, he often did not dare to state explicitly the consequences he foresaw in his own discoveries.[29]

Thus, Cahours did not advocate publicly a système like his contemporaries, who were keen on publicising their ideas both inside and outside the scientific community. Rather, the work produced by his research laboratory was based on a hidden agenda, which only his élèves publicised within the scientific community and to do that, they had both the agreement of their maître and the back up provided by Wurtz's école. This may explain why sometimes Cahours's école was omitted from some accounts on the Parisian écoles of chemistry[30].

Despite the limitations that Cahours presumably was led to impose on himself, inasmuch as he was teaching at the Ecole Polytechnique, these did not prevent him from working with Hofmann[31] in England on derivatives of allyl alcohols (1856), and Hofmann was a clear advocate of Gerhardt's type theory and atoms. Moreover, they also did not prevent a close association between his own research and that of his élèves. Thus, back in 1853-1854 Cahours and Riche both carried out investigations on organo-metallic compounds, particularly on organic derivatives of tin and arsenic which resulted in the publication of two joint articles.

These studies and their further developments by Cahours helped him in his election to the Académie des Sciences in 1868. Demarçay, who entered Cahours's laboratory in 1875 developed research until 1882 on organic chemistry and also on organo-metallic compounds, especially organic derivatives of tin. He, therefore, published, six joint papers (1875-1880) with his maître. Later, Demarçay moved to a different area, becoming an expert on rare earths and spectroscopy, through the investigations he carried out in his private laboratory (1882?-1901). Finally Etard, who worked on alkaloids while attending Cahours's research laboratory, also published with his maître three joint papers on nicotine between 1879-1881. In 1880 he also became préparateur of the laboratory of biological chemistry at the Faculty of Medicine, and in 1882 he was asked by Gautier to collaborate in his investigations on ptomaines.

The other remaining élèves also published joint papers with Cahours: Jolyet published four papers on the physiological activity of some organic compounds related to aniline (1868-1869); Pélissard published in this same field but involving conine derivatives (1870) and Gal published four articles on organo-metallic compounds (1870). This suggests that, after an average of three-six joint papers with Cahours, the élèves started to publish independently.

The élèves of Cahours engaged in several activities in the scientific community, but very much as associates of the école of Wurtz, since the dimensions of their own did not allow them, as a group, to launch and control initiatives, such as scientific organisations and publications. They followed their maître as members of the Société Chimique de France created in 1858, of which Cahours, together with Thenard (son), Pasteur and Berthelot became one of the four first vice-presidents[32]. Riche and Etard[33], also participated in the editorial board of the journal published by that organisation, joining in this task Wurtz and his école. In addition Demarçay, who had among his close friends Wurtz and his élève Friedel[34], collaborated with various articles in 1879 in Wurtz's Dictionnaire de chimie pure et appliquée and the same happened with Etard. After being awarded the Jecker prize[35] (1880), Demarçay was from Cahours's élèves the only one who was elected to the Académie des Sciences in 1881, taking the place left by Regnault.

Despite the possible constraints that Cahours may have had to face and the influence of his personality upon the shaping of his research group as a modest one in size, it emerges that his école, by deliberately avoiding tension and controversy acted as a factor of stability in the highly competitive chemical scene of Paris. Thus, particularly its scientific contributions which were framed within the atomic theory, ostracised at the time by the official science, quietly reinforced within France the work of others who were advocating it, inasmuch as the research published had its origin at a laboratory established within one of the grandes écoles. Moreover, as regards chemical theory, Cahours's election to the chemistry section of the Académie des Sciences together with the election of Demarçay contributed to balance the forces within that influential institution.

2- Henri Sainte-Claire Deville (1818-1881) and his école.

2.1 The maître: his career and public image.

Henri Sainte-Claire Deville, who inspired Dumas's portrait of the ideal chef d'école, was born in St. Thomas (Antilles) where his father was shipowner and Consul of France in that Danish colony. However, he was to receive a French education, since he was sent to Paris to be educated in the Collège Rollin, and later he studied medicine also in Paris. It was while attending the Faculty of Medicine that his interest in Dumas's lectures at the Sorbonne was awakened, and he decided to follow them. Like Cahours, he then did research on organic chemistry in Dumas's private laboratory, where he also met Wurtz.

His investigations in Dumas's laboratory were devoted to organic chemistry, and in 1840 he published papers on turpentine oil and several derivatives of terpenes, which were followed by a piece of research on toluene in 1842. These investigations brought him the recognition of the Parisian chemical community especially of Dumas and L. J. Thenard, but he then abandoned organic chemistry to engage almost exclusively in research on mineral chemistry. For reasons which are to be discussed later on[36], the potentialities of mineral chemistry at the time seemed to many chemists to be almost exhausted, and the mainstream of chemical research was undoubtedly focused on organic chemistry. From this point of view and because Deville was also to engage in applied research due to his relations with Dumas and the Emperor, he was to carve an unique place not only in the French chemical scene, but to a certain extent at an international level.

In 1845 L. Thenard, at the time a member of the Conseil de l'Université, appointed Deville as Dean of the Faculty of Sciences at Besançon[37] (1845-1851), but with Dumas's patronage he returned to Paris to replace Balard at the Ecole Normale, a school devoted to the training of teachers for the lycées, when the latter became professor at the Collège de France (1851). From now onwards Deville's career, like that of Cahours, was to develop under the auspices of Dumas and also following the usual patterns of cumul and suppléance. Thus, he was appointed to replace Cahours in his capacity as Dumas's suppléant at the Sorbonne, a post that Deville was to hold between 1853-1866. The 13 years of substitute lecturing at this institution may be mentioned as evidence of the extent to which Dumas, now heavily engaged in politics and state affairs, kept the control of the system through his former élèves, by establishing in this way a network of loyalties[38]. Moreover, Deville's election to the mineralogy section of the Académie des Sciences in 1861 added to his reputation and his capacities for patronage were substantially increased. However, this election also revealed his negotiating skills, since he only agreed to become a candidate after the election of his brother, the geologist Charles Deville.

Although Deville had never formally involved in political tasks he was committed to the Empire, and in addition to his academic career he was invited to join the administrations of the Parisian gas company and the Eastern railway of France[39].

Deville was portrayed by his élèves as having a joyful and enthusiastic personality, and as a maître who took his élèves fully into his confidence. Moreover, he was also described as a chef d'école, who did not impose his views on the élèves, which was not probably necessary because, in many cases, it was he who selected them among his own students of the prestigious Ecole Normale. Like Cahours, Deville was also described as inclined to offer "fatherly advice"[40] to his élèves, an attribute that, at the time, was in general greatly valued especially by the trainees. As an example of how this father-like posture was revealed at a practical level it can be mentioned that, for instance, he decided to pay the dowry of the bride of one his élèves[41]. Moreover, in terms of patronage, his élèves compared him to Dumas and Thenard.

Deville was particularly admired in the French chemical community including his élèves and colleagues, who provided representations of him in which he was described as a hard-working and patient savant , engaged in painful and dangerous areas of chemical research[42] and providing a moral example for young people, since devotion to science was seen as a patriotic activity.

These moral values appended to the images of savants were not obviously restricted to Deville and, as it will be seen later on, generally corresponded to a transference of Christian moral values to the realm of scientific life, which were ultimately justified in rhetorical terms by arguments on behalf of public welfare and national imperatives. Moreover, the figure of the genius so dear to the Romantics, since it was the ultimate expression of singularity[43] continued to be used as a form of describing men of science, but from a new point of view. This different perspective had been introduced by the positivist trend, in which the attributes of the genius instead of being seen as an innate, unique and uncontrolable driving force[44] were seen as something achievable through a strong commitment. Thus, Deville deserved from his positivist and agnostic colleague Berthelot, the following comment, in which his theory of dissociation was seen as almost a providential reward for someone who achieved the status of a genius through patient work:

> It (dissociation theory) was the deserved reward of that enormous patience, which may be regarded as a form of genius.[45]

However, at least once, Deville portrayed himself as a disenchanted savant:

> Perhaps this work with aluminium, which has taken from me my money and the best of my time, is getting the best of me. I am tired and bored with life.[46]

2.2 The élèves

The prestige associated with Deville's professorial duties at the Ecole Normale decisively contributed to attract élèves to his research laboratory, but unlike Cahours, who only had both the usual official budget for laboratory teaching and the junior teaching posts available to recruit élèves, Deville was to have other benefits. The private economic support that he was able to obtain through Dumas from Napoleon III together with that he also obtained from the Académie des Sciences enabled him to have one of the best equipped laboratories in Paris, and these factors were also to determine the number of élèves he was able to recruit.

Deville's élèves can be divided into two broad categories, taking into consideration the process of recruitment involved: those who were former students of the Ecole Normale, the Normaliens[47], and the outsiders, the non- Normaliens[48]. About 30 have been identified, in both categories. The first category represents about one half and a striking feature was the high rate (about two thirds) of doctorates obtained by these élèves. Furthermore, while they were preparing for their doctorate they followed a common procedure, which consisted of serving successively in the junior teaching post of agrégé-préparateur in Deville's laboratory and often many held other posts simultaneously in Parisian lycées. After obtaining their doctorates they were appointed to teaching posts in Faculties in the provinces, or in similar institutions of higher education in Paris[49], under Deville's patronage. This ultimately implied the control over not only chemistry teaching at the lycées, but also in the institutions for higher education in the provinces to which was added Deville's membership in the Conseil de l'Instruction.

On the other hand, the non-Normaliens, who included two foreigners, entered Deville's laboratory to receive training under a private arrangement[50], but it is not apparent that they had ever paid a fee even to cover their own expenses in reagents and apparatus. Moreover, with the above mentioned funds and those that were to be allocated during the Third Republic, Deville was apparently able to respond to the external demand. According to the testimony of Figuier, editor of the journal L'Année Scientifique et Industrielle:

> For one third of a century, the laboratory of Deville had always been a place where scientific hospitality was never refused...resources were easily given and for this reason often the balance of the official

budget was almost compromised.[51]

In addition to his élèves working on chemical subjects Deville also had a few young savants studying subjects other than chemistry who, due to lack of facilities elsewhere, used the premises of the Ecole Normale, which enabled them to perform their experiments, or to prepare their doctorates with his advice[52].

Among the élèves it is possible to identify a group composed by the Normaliens: Debray[53], Troost[54], Gernez[55] and Joly[56], together with the non-Normalien Hautefeuille[57] that constituted a "hard-nucleus", i.e., a permanent group of élèves who, being closely and almost permanently associated with Deville for many years, helped in laboratory training tasks and in maintaining both the cohesion and influence of the group. This situation was made possible by the posts to which these élèves were appointed, both at the Ecole Normale and at the Sorbonne. Some of them, Debray, Troost and Hautefeuille, together with others like Ditte, Fouqué, Lechartier, Damour and Cailletet added power to Deville's école through their election to both the chemistry and mineralogy section of the Académie des Sciences. Such a number of Academicians had no parallel when compared with the other écoles.

2.3. The école

Generally speaking, Deville, despite having never claimed to be sympathetic to Positivism, adopted an approach to chemistry which may be framed in the version that many savants of his time, chemists or not, made of Positivism without following completely the prescriptions put forward by A. Comte. From this point of view Deville's perspective of chemistry was similar to that of Berthelot who, however, revealed additional similarities with Comte from the ideological point of view. Therefore, Deville's approach consisted of considering chemistry as a natural science, which should be subordinated to macroscopic physical laws, but unlike Comte's[58] Positivism, Deville rejected the value of theories and hypotheses[59]. Instead, for him the experiments did not have the role of verifying theories as Comte prescribed. For Deville, as indeed for many who were currently identified with Positivism, experiments merely provided observations from which it was possible to classify substances and phenomena through analogies established at a macroscopic and observable level. Consequently, as he rejected any sort of classification based on inner and non directly observable properties, since they implied the formulation of hypotheses, Deville rejected the atomic theory[60]. He based his approach to matter on a strict substantialism, adopting a position of extreme empiricism.

Basically Deville was an experimentalist, who focused on mineral and physical chemistry and their applications, which were fields where the atomic theory could more easily be dismissed. As Olivier was to point out :

> Almost all specialists of mineral chemistry are obstinate in discarding the atomic theory for misoneism or the tyranny of an école and also because it is not so necessary in their particular studies.[61]

His own research on mineral chemistry had begun in the 1840s, and his first discovery was that of nitrogen pentoxide in 1849. After some investigations on carbonates of various metals he engaged in research for the preparation of metallic aluminium (1855). In particular, he developed a process for obtaining that metal in a pure form by reducing its salts with sodium. With these investigations, Deville contributed eventually to reducing the costs of production of both sodium and aluminium. Dumas brought these results to the attention of the Emperor and it was in this way that his support was obtained[62].

As regards the investigations of his élèves, they were closely related to Deville's current research. In particular they focused on subjects of mineral and physical chemistry and especially studies on metals, production of artificial minerals and dissociation phenomena. Thus from Deville's methods developed for the preparation of aluminium, extensions were made by his élèves for the preparation of silicon, boron and titanium. In the field of metallurgy, together with Debray he carried out extensive research on the metals of the platinum group (1859-1862). At the same time they developed technical investigations on furnaces to obtain high temperatures as well as techniques to measure them. As regards the principle of dissociation (1857)[63], which at the the time was generally seen as a major achievement, the élèves who most engaged in this area were Isambert, Gernez, Troost and Hautefeuille.

Deville and his école took part in activities in a wider context both formally and informally. Their laboratory was used as a place for gatherings in which industrialists, intellectuals, sometimes foreigners participated, and the maître himself and his école were promoted. According to one account:

> Open house was held regularly. After a week of full activity there was a brisk clean up, early Sunday morning, and then the doors were opened to all: students, alumni, friends, philosophers, mathematicians, industrialists, naturalists and scientists of all varieties, formed these informal gatherings pleasant and instructive. Deville demonstrated his new findings or discussed scientific topics.[64]

Deville also took part in the foundation of the Société Chimique de France and in 1863 he was elected its president. Although he had delivered lectures at the Société, he did not publish often in its journal[65]. Yet some of his élèves such as Caron, Debray and Hautefeuille engaged in both the foundation and further activities of the Société, and Troost, Lamy and Hautefeuille were respectively elected presidents in 1867, 1873, and 1877. However, they never had the control of the Société's journal. As regards the channels for publication they were, as in Cahours's case, mainly the Comptes Rendus and the Annales de Chimie. The number of joint publications is particularly striking since Deville published about 40 joint papers with his élèves, but these articles were confined only to a few like Debray, Troost and Caron. Those belonging to the "hard-nucleus" usually published jointly with the newcomers. This behaviour as a patron followed the model of the école of Dumas in which independent publication was exceptional for those under training .

3- Louis Pasteur (1822-1895) and his école.

3.1- The maître: his career and public image.

Louis Pasteur was born into a very modest family of craftsmen of Dole (Jura), and after receiving his secondary education, he came to a Parisian lycée (1843) to prepare his admission at the Ecole Normale. During his youth he was to manifest a special skill for painting, but he decided not to follow an artistic career. While attending the Ecole Normale he was attracted, like Deville, by Dumas's lectures at the Sorbonne, which he attended, but he never carried out research in Dumas's private laboratory. Instead, he worked in Balard's laboratory at the Collège de France with Laurent on crystallography, and later he had as guide the crystallographer Biot, who was also to become Pasteur's patron. Nevertheless, he maintained throughout his life regular contacts with Dumas, who supported him on many occasions, playing an influential role as his patron[66].

After graduating from the Ecole Normale and completing his doctorate, Pasteur was appointed Balard's préparateur at that institution, but he then moved to Strasbourg (1849-1854) and to Lille (1854-1857). In 1857 he attempted to be elected to the Académie des Sciences, with Dumas's support, but he failed, being admitted in 1862 in the mineralogy section. Also in 1857 under Dumas's patronage he was appointed director of scientific studies at the Ecole Normale. Here he found no laboratory facilities and in a letter addressed to the Minister of Public Instruction (1858) he asked for funding to make suitable arrangements[67]. He did not succeed immediately, but in 1859 he was finally settled in.

In 1867 he was dismissed from his post of administrator and director of scientific studies at the Ecole Normale owing to his unpopular, often considered implacable and arbitrary behaviour towards the undergraduates of that institution. However, he was given a compensation for the loss of his post as administrator: he was appointed professor of chemistry at the Sorbonne, and was allocated a new research laboratory for physiological chemistry at the Ecole Normale, under the auspices of Dumas and Napoleon III. Through Dumas's influence a sum of 60,000fr. shared by the Emperor and the Ministry of Public Instruction was to be spent in the establishment of this research laboratory[68].

As a chef d'école Pasteur's image did not correspond very closely to the ideal previously presented by Dumas. Pasteur was less a father-like figure than Deville or Cahours, and was to be represented by the metaphor of the apostle:

> He [Pasteur], obeyed all his life to the purest ideal, to a superior ideal of science, of virtue and charity...he was great by his intelligence and the future will include him in the shining lineage of the apostles of goodness and truth.[69]

Pasteur was a Catholic and, furthermore, he was made the symbol of the Catholic savant who struggled with the positivist and agnostic Republicanism; later his physiognomy was even compared with that of Saint Vincent de Paul[70]. During the Third Republic, Catholic savants teaching at higher education were under surveillance, since the regime feared that they might use their position for ideological purposes[71]. Pasteur emerged, therefore, as the Catholic symbol of savant, who had been able to conciliate science and religion. In fact, he was portrayed by his disciples as a kind of a "spiritual leader" or an isolated genius, as the title of the book Pasteur, l'histoire d'un esprit by his disciple Duclaux clearly suggests. But, his reduction to his esprit was in practical terms described by his nephew and élève Loir:

> He wanted to be alone in his laboratory and never spoke of the goal he had in mind...he would write on small cards the experiments that he wanted to have done and then, without explaining anything would ask his assistants...to do them.[72]

However, the loyalty of his most devoted disciples seem not to have been shaken by his attitude and according to the description of Duclaux:

> I believe that never before had such a united community had ever surrounded a leader. We were not, I should say aware of what was in Pasteur's mind, because he was, at this period, a secretive worker, keeping his projects and ideas to himself. But, we guessed or we thought we were guessing and this was enough to provide a challenge and keep us interested.[73]

3.2- The élèves

In the establishment of his école, the recruitment of Pasteur's élèves reveals some peculiarities. Apparently underlying his recruitment procedures, the main driving force seems to have been the necessity of making up for his own "limitations", rather than the wish of training élèves for a research career. His "insufficiencies" were not only related to the extraordinary wide range of subjects he investigated, but also to his physical disabilities. Pasteur had suffered a cerebral palsy in 1860, which paralysed his left side, preventing him from performing most of his laboratory work. His role consisted mainly of directing the experiments which were mostly executed by his collaborators, but strictly controlled by him. Furthermore, when he moved to the realm of medicine (1877), he had not only to face his partial paralysis, but also his ignorance in medical and veterinary subjects as well as his repugnance towards vivisection[74].

Thus his élèves were recruited, especially at the beginning, among Normaliens, in a way similar to that of Deville, but also among medical doctors. However, he seemed to have trained directly only a few of his disciples and it is symptomatic that in Frémy's description of the écoles of chemistry of Paris in all cases he mentioned the maître, sometimes with a father-like posture[75] surrounded by his élèves but, in the case of Pasteur, his powerful figure in the research laboratory had the effect of removing from descriptions any reference to his disciples. In fact, Pasteur showed little interest in their recruitment and several left his research laboratory at an early stage in their work due to his almost complete indifference[76].

However both in his research and in the transmission of his methods and beliefs, Pasteur had strong support from two of his élèves: Duclaux[77], a Normalien, and Roux[78], a medical doctor. To the greatest extent they epitomised the model that Pasteur's disciples followed, and in practice, they became responsible for the recruitment of others[79]. Duclaux entered Pasteur's laboratory in 1862 as agrégé-préparateur, when the debates over spontaneous generation erupted (1862-1865). After his doctorate in 1865, he went to teach at the lycée of Tours and at the Science Faculty of Clermont-Ferrand, where he met Roux as one of his students. Although it was not part of his duties, he renewed his collaboration with his maître in the provinces on three separate occasions and he only came to Paris in 1878 as professor of physiological chemistry at the Sorbonne. Later, he transferred his teaching activities to the Institut Pasteur, when this was founded in 1888 . He succeeded Pasteur at his death in 1895, as director of this institution. Duclaux had imparted to Roux his enthusiasm for Pasteur while he was lecturing at Clermont Ferrand and after graduating in medicine from that university Roux came to Paris in 1878 to be appointed as Pasteur's assistant in his laboratory at the Ecole Normale. In 1888 he became professor of microbiology at the Institut Pasteur and succeeded Duclaux at his death in 1904 as director.

Both Duclaux and Roux were above all the pillars on whom Pasteur based the development of his research enterprise in the long run. This enterprise consisted basically of the dissemination of Pasteur's methods closely linked to his esprit, i.e., to his aura of an illuminated genius devoted to the welfare of mankind. However others were committed to this mission and among them the two Normaliens Chamberland[80] and Thuillier[81], the medical doctor Calmette[82] and the several foreigners, like Metchnikoff[83], who came to Paris to be trained according to Pasteur's methods.

3.3 The esprit and the école

Pasteur's école relied rather on his quintessential esprit, which was transmitted by his closest disciples, than on his physical presence and on his personal laboratory practice. His esprit embodied a set of representations of science, with which he associated moral Christian values as well as emotive patriotic feelings. He was keen on publicising these ideals, especially through articles devoted to popularisation in journals like the Revue Scientifique, which, in addition, regularly reported his scientific performances to a large audience. Pasteur's image of science incorporated nationalistic features, especially after the Franco-Prussian war, which he used as an argument to decide on the "truth" of his experiments. Notably, during the debate over fermentation which took place between him and Liebig, Pasteur was to accuse his fellow countrymen Frémy and Trécul of being anti-patriotic: they were defending a "German theory" against a "French theory".[84]

Pasteur also represented science as an activity which involved passion and permanent hard-work [85] through which the "idea of the divine expands and is exalted"[86] and consequently was justified as the moralising force of "modern civilisation":

> To the extent that we arrived at what is called modern civilisation, the cultivation of sciences in its highest expression is more necessary to the moral state of a nation than to its material prosperity.[87]

As such, to some extent he represented the savant in a Romantic fashion, i.e., as someone who isolated in his laboratory was, "religiously" working for the sake of mankind[88]. For this reason in his image, the savant owed little to the state and being located above it, should deserve its recognition and support[89].

Pasteur, was described as very strict with the laboratory. Silence was a golden rule and he was almost obsessed with cleanness due to his fears of infections[90], and did not tolerate the presence of certain comforts[91]. His representation of a laboratory was, therefore, that of a church-like space, as he emphatically expressed:

> These sacred places, which we called expressively laboratories...the temples of the future, of richness and welfare.[92]

Pasteur's ideology was transmitted to his élèves, particularly to those he chose as his successors Duclaux and Roux. As the former metaphorically mentioned, they received "the flame that lights up the temple"[93] and eventually became in charge of the Institut Pasteur. Duclaux, also had an image of science as a universal panacea, but unlike Pasteur he had a more internationalist ethos, advocating an universal brotherhood under the banner of science:

> Science is the common Fatherland, where one could have passions without having hatreds.[94]

However, the creation of the Institut Pasteur, which occurred during the Third Republic a regime to which Pasteur was hostile, was based on an international subscription, and itself resumes Pasteur's esprit. Its architecture resembles that of a religious building in which Pasteur, like a "founder apostle", was buried in the crypt and the vault over his grave has four great white angels representing Faith, Hope, Charity and Science[95]. The mission was not confined to France, but it spread all over the world by opening new "temples", which were intended to continue the work of its founder. Moreover, the Institut Pasteur also substantiated the "crusade-like" activity of Pasteur's école , which possessed a special corps of disciples who often risked their lives in missions abroad[96] in campaigns against diseases. In the eyes of Pasteur these "martyrs" of science as he understood it, constituted an example for youth, although he did not dare to say it publicly. In a letter he sent to Roux, giving instructions for the speech, to be delivered in Thuillier's funeral in Egypt where he died during an epidemic , Pasteur mentioned:

> It would be invidious for me to present Thuillier as an example to young people...Thuillier had certain qualities of the great warriors.[97]

But to use the words of one his disciples, Fernbach, it is now time to go on

> a pilgrimage to that immense and harmonious temple, which had been built up by his scientific work.[98]

and look at the research carried out by him and his disciples.

As regards research, Pasteur's experiments covered an enormous variety of subjects, most of them with practical application, although the underlying principles presented a great unity, according to some historians[99]. Pasteur used basically the same kind of approach in his various studies, i.e., he transformed practical problems into theoretical questions, which opened up new fields of research to be further developed by his disciples. For instance, he studied ferments with the approach he had applied to crystallography and always starting by a historical balance-sheet of each problem followed by experiments to test his intuitions and hypotheses. Between 1847 and 1857, he had been engaged in studies on crystalline asymmetry, but by the time he began establishing his research laboratory, he moved on to experiments on fermentation and spontaneous generation. The main fields embraced together with his disciples have been summarised by Geison[100] as follows:

1847-1857- Crystallography: optical and crystalline asymmetry.

1857-1865- Fermentation and spontaneous generation; studies on vinegar and wine.

1865-1870- Silkworm diseases; pébrine and flacherie

1871-1876- Studies on beer; further debates over fermentation and spontaneous generation.

1877-1895- Etiology and prophylaxis of infectious diseases: anthrax, fowl cholera, swine erysipelas, rabies.

In these subjects Pasteur was greatly helped by his élèves and thus Duclaux collaborated on the investigations on silkworm diseases, fermentation, brewing industry[101] and on rabies. His later scientific activity provides a good example of Pasteur's disciples[102] as explorers of research areas initiated by their maître. Following up Pasteur's work, he concentrated on fermentation processes and was led especially to the study of diastases (enzymes) and related phenomena, including their application to agriculture, industry and medicine. In their turn Roux together with Chamberland and Thuillier worked on anthrax and attenuation of viruses which led to the preparation of vaccines. After having improved vaccines against chicken cholera and anthrax, Roux engaged in experiments which dealt with the prevention of rabies. His name is particularly linked with studies leading to diphtheria prevention, which culminated in 1894 in the application of the anti-diphtheria serum.

As regards publications, it is difficult to assess the extent of independent publication, as regards the disciples, since for instance Duclaux, despite his close and permanent collaboration with Pasteur, never published joint papers with him, which may suggest Pasteur's appropriation of his work[103]. In addition, Roux also wrote few articles on his own before 1890 and the few papers he published were jointly signed by him and Pasteur, which may be justified by Pasteur's necessity of accreditation within the medical community. However, none of Pasteur's disciples ever complained publicly. Pasteur was himself very committed to establishing his own priorities over intellectual property, but he was said to be intolerant to criticism[104], which may have prevented reactions from his disciples.

Looking at this brief summary of the research carried out by Pasteur's group, we realise that in modern terms these subjects transcended the realm of chemistry. However the inclusion of his école in this account on the network of Parisian écoles of chemistry is justifiable for several reasons. One was the intrinsic features of Pasteur's research, which consisted of widening and introducing research fields, which he left at a certain stage to be continued and further explored by his disciples in different directions. Another, was the scope of chemistry at this period and its related level of specialisation. As Brooke[105] pointed out, chemistry could be seen at this stage as a tripartite science, ranging from mineral to physiological chemistry, with organic chemistry in between. In addition the designation of physiological chemistry covered a great variety of fields, sometimes closer to chemistry, others closer to biology, but especially to medicine.[106]

A final reason was that Pasteur and some of his disciples held teaching posts related to chemistry, competing with the other groups for these places. This is particularly relevant if the recruitment procedures of élèves, based on appointing them to the available junior teaching posts is taken into account. Also the influence that the écoles were able to obtain from a reasonable coverage of institutions of higher education in Paris has to be considered. Pasteur himself provides an example of this competition, when he contested Berthelot's appointment to the Collège de France. Although he protested against the coup through which Berthelot acquired this controversial professorship, Pasteur notably invoked his credentials as a chemist to claim his rights to that position[107].

As a chemist Pasteur participated in the foundation of the Société Chimique de France as one of its earliest vice -presidents, and later as president in 1860, 1865 and 1869. Also some of his disciples were members of de Société Chimique and participated in the editorial board of its journal. The research group of Pasteur was also to found and control a publication, the Annales de l'Institut Pasteur, created in 1888 by Duclaux.

As mentioned before, Pasteur was keen on publicising his work in popularisation journals. In addition he usually presented the Imperial family with copies of his publications and on some occasions entertained the Empress and guests with his experiments. He also implemented a practice similar to that of Deville, which consisted of salon-like sessions at his laboratory where he attracted, as Duclaux mentioned, potential supporters:

> The laboratory had aristocratic visits, savants, publicists and industrialists who came to observe with the microscope this new world of the infinitely small.[108]

4.- Marcelin Berthelot (1827-1907) and his école

4.1- The maître: his career and public image.

Marcelin Berthelot was born in a Parisian bourgeois family. His father was a medical doctor and his mother a very devout Catholic . Berthelot had a strict Catholic upbringing, but later in adult life he was to reject Catholicism[109]. His secondary studies were carried out at the Collège Henri IV. While a pupil at that institution he met Taine and Renan, who greatly influenced him, and he was awarded a national prize on philosophy. After completing his baccalauréat ès lettres he attended several courses in the Faculty of Medicine and at the Sorbonne, from which he graduated in 1849. Later, he was also to graduate in Pharmacy (1858), but before starting his professional career he was to travel, like many young men of the time and following the Romantic fashion, in Italy and Germany.

His education and career did not follow the same patterns of the previous chefs d'école, since neither did he attend or even teach in any of the grandes écoles, nor did he carry out research in a prestigious research laboratory such as that of Dumas, during his youth. Instead, he attended Pelouze's private laboratory (1849), where he learnt appropriate skills to become soon a préparateur. Two years later, he was appointed Balard's préparateur in his laboratory at the Collège de France, and in 1854, he obtained his doctorate in physical sciences at the Sorbonne.

Meanwhile, he decided to study at the Faculty of Pharmacy, which he attended between 1854-1858 because he foresaw there a future post, since all other Parisian institutions of higher education were taken as far as chemistry professorships were concerned. As his devoted élève Jungfleisch expressed it, he was "anxious to open the doors in front of him"[110], and indeed Berthelot, the youngest of these chemists, was committed to fight for a place in the French chemical scene. In fact, he was appointed as professor of organic chemistry, a chair especially created for him with Dumas's support, which was obtained through Balard, during Duruy's ministry.

His main coup, however, was to occur in 1863, when he was nominated by Duruy, at Balard's suggestion, as professor of organic chemistry at the Collège de France, an institution of great traditions, which conformed to the spirit of a French civilising mission. This nomination was surrounded by peculiar events, which were to provoke reactions of indignation from savants like Pasteur and Wurtz. Particularly the latter, who was ten years older than Berthelot and, working in the same field, already possessed an international reputation, which Berthelot was far from reaching. But apparently, what both Pasteur and Wurtz above all criticised was the procedure used by their colleague to obtain this post.

Berthelot's appointment had been preceded by the publication in the Journal de l'Instruction Publique[111] of a petition addressed to the Minister of Public Instruction, which caught his adversaries by surprise. In this petition the creation of a course on organic chemistry was advocated, and Berthelot was presented as the most suitable chemist[112] for the post. This public document had been instigated by him and signed by seven senior professors[113] among them Balard and Dumas. Pasteur immediately reacted, sending his protest to the Academy, the Minister, Berthelot, and inevitably Dumas[114], to whom he expressed his surprise of seeing him involved in a conspiracy that he attributed to the école positiviste[115]. In relation with Berthelot's post at the Collège de France Wurtz also expressed to Dumas[116] his deception, particularly because the petition portrayed Berthelot as the single representative of organic chemistry in France and the author of a new chemical philosophy, dismissing his own contributions as well as those of other French chemists[117].

Berthelot, however, did not immediately obtain what he wanted, mainly because the ministerial officials had their reservations about what they considered Berthelot's excessive presumption. For the moment he had to content himself[118] with the mere creation of a complementary course on organic chemistry. But, in 1865, the new chair of organic chemistry was officially created and at the age of 38, he was at the Collège de France[119] with a research laboratory. Using this new position, Berthelot established his école, which he developed substantially, especially from the late 1870s onwards, as the result of three major events: the creation of the Ecole Pratique des Hautes Etudes (EPHE) (1868), his election to the Académie des Sciences (1873)[120] and his move from organic chemistry to thermochemistry.

Since his youth Berthelot cultivated a close friendship with Renan[121], a historian and philologist, which developed into an assiduous correspondence that Berthelot was to publish later after his friend's death. Renan was a man who went through a deep period of "malady of soul" (maladie du siècle) becoming an agnostic in 1845, although longing for some sort of religious comfort. Berthelot, was to take a similar decision, and adopted Positivism as a doctrine that, in his personal reading, he wanted to prove right through his scientific practice. In his correspondence with Renan, Berthelot since he was young showed that feature so often manifested in the Romantics that he was almost predestined to a special mission. That mission was to become the apologetic of his positivist philosophical doctrine. He was to epitomise his doctrine in the materialisation of a scientific Utopia predicted for the year 2000, in which chemistry was to play a central role. In order to publicise his ideas and obtain support, he was to attend while a young scientist several Parisian salons where he met Romantic writers like George Sand and Théophile Gautier, the Goncourt brothers[122], and later the positivists Taine and Littré as well as other Republican intellectuals and journalists. Particularly the latter promoted quite effectively mainly in newspapers Berthelot's views and early scientific production, which amazed them chiefly due to their lack of knowledge of science. Throughout his life Berthelot was to cultivate social relationships with politicians and journalists, from whom came much of his support.

As a chef d'école, Berthelot was portrayed by his protégé Jungfleisch as follows:

> Berthelot was able - only as few researchers could- to guide his assistants of different kinds and obtain from them the maximum work they were capable of giving to him.[123]

This image was corroborated by Berthelot himself[124], but what was seen as his major quality was for other élèves something different. In fact, few other portraits of Berthelot in which he was presented as a maître who merely took advantage of a highly qualified work-force, the Normaliens, are available. Thus, according to the comment of his élève Delépine[125] on his colleague Matignon:

> Berthelot profiting from a competent aid [Matignon's] associated him in several of his investigations...we may figure out easily that it was Matignon who really performed the experiments.[126]

In addition, he had also the image of a very assertive maître and one who was hard to please:

> Berthelot was very demanding and imposed on his collaborators the continuous repetition of the same experiments[127]

These kind of portraits were not frequent .Instead, other more cautious were produced, given Berthelot's possible retaliations due to his high standing within the establishment.

In fact, Berthelot added to his scientific profession a political career[128], occupying several positions in government during the Third Republic. Although traditionally French men of science were often involved in politics, they were sometimes portrayed, especially after the French Revolution, as isolated figures distanced from mundane affairs[129]. Now, what was to change was that the Positivists, including Berthelot, presented the political involvement of savants simultaneously as an extension of their status and as a patriotic duty. Given the nature of their activity they were seen as being the most prepared to ensure social order and the progress of the country:

> The savant and his services are required often demanded imperatively, at different levels in the name of public interest: either special applications to industry or the national defence, public

teaching, in short general politics.[130]

As a savant, Berthelot like Pasteur, was also represented as an apostle:

> When he [Berthelot] addresses to democracy, when he accomplishes his duties, when he wants to ennoble through a rational education, he only regards this generous propaganda as a necessary continuation of his scientific apostolate.[131]

which indicates how Christian moral values were transposed to science, and how Positivism was seen as the Republican reassuring substitute. Berthelot became a national symbol and was to be "canonised" by the Republican regime[132]. When he died he had national funerals and was buried in the Panthéon with all pomp and circumstance. Afterwards, several national celebrations took place in 1917, 1927 and 1937 to honour his memory.

4.2- The élèves

Although the creation of the EPHE (1868) had benefited Berthelot's fellow chefs d'école, it did not do so to the same extent, since their écoles had already been working for several years. But in the case of Berthelot, it supplied the bureaucratic means to launch and run his école at government expense . The EPHE was a mere superstructure covering institutions depending on the Ministry of Instruction. According to the statutes its council had advisory functions in the creation and endowment of research laboratories by the Ministry[133] but, in practice, it basically recognised the research laboratories already existing, by providing them with proper accreditation. Berthelot benefited from the EPHE mainly because he was now able to appoint his élèves as research assistants and not merely to the available teaching posts as in the case of other chemists like Cahours or Deville. Comparatively he had a considerable economic power, which increased as his influence in political circles and his political appointments were developing, especially during the Third Republic. Hence, he was able to gather around himself a large number of élèves, and in terms of size, it is the only école comparable to Wurtz's.

According to Jungfleisch, Berthelot's junior collaborators may be divided into two types:

a) the ones who had research duties: préparateurs, préparateurs-adjoints and volontaires, the two first corresponding to official posts.

b) those having only teaching duties, the préparateurs du cours.

Most of his collaborators with teaching duties, the préparateurs du cours, did not engage in research , unless they volunteered to do research at the Collège de France, as in the case of Jungfleisch. Particularly at the Faculty of Pharmacy, these préparateurs du cours were committed only to teaching duties. Although there is room for a deeper study, we may conclude provisionally that among Berthelot's élèves, only the préparateurs, préparateurs-adjoints and the volontaires, both French and foreign, carried out research under his supervision[134].

While for Pasteur the choice of a collaborator was a minor question, for Berthelot it was really a matter of great concern. In fact, especially after his election to the Académie des Sciences and with his increasing personal power, he depicted a special strategy for recruitment. His procedure consisted of recruiting elite élèves among the most capable graduates of the grandes écoles, and appointing them to the above mentioned research posts in the Ecole Pratique des Hautes Etudes at the Collège de France. As his élève Delépine emphasised:

> At this period of Berthelot's recruitment of élèves, in fact he was really committed to look for Normaliens wishing to work in his laboratory. He had at his disposal subsidies, which enabled him to appoint them préparateurs at the Ecole Pratique des Hautes Etudes.[135]

These young research assistants, usually stayed with him one or two years, time enough for them to prepare a doctorate, and after its conclusion, Berthelot used his influence to further their careers in the faculties in the provinces.

Many of his élèves did not come to him spontaneously, but because of economic motivations as, for instance, the case of Guntz[136] exemplifies. As a Normalien , Guntz had been strongly influenced by Deville's and Debray's lectures. His inclinations, however were towards the research carried out by Pasteur, whom he would like to have followed. But the perspective of both a salary and a doctorate by joining Berthelot, became rather important in his particular financial situation[137]. Also Sabatier[138] provides a good example, at the same time it shows how much Berthelot was influential and able to deal with bureaucracy and administration. As Mary Jo Nye says:

> When Marcelin Berthelot asked the Ecole Normale's director to recommend a Normalien for his laboratory the director proposed Sabatier. Berthelot wrote to Sabatier that he was obtaining a leave-of-absence from Nîmes with the understanding that he should return to secondary teaching if a scientific career did not offer the chances of success.[139]

In the laboratory some of his élèves apparently did feel restrained, since there were no allowances for personal creativity or originality and Berthelot's plans had to be strictly followed. Some cautious testimonies hinted at Berthelot's egocentric attitudes and some boredom from his élèves:

> Before pursuing personal research, the préparateurs had to devote many hours each day to work of "general interest", whose monotony was as certain as its utility. [140]

But while Guntz and Sabatier may be envisaged as typical cases of Berthelot's élèves of the most flourishing period of his école, corresponding to the thermochemistry phase at the Collège de France, Jungfleisch[141] represents the model of élève of the earlier stage, corresponding to the organic chemistry phase at the Faculty of Pharmacy. Holding a teaching post at this Faculty since 1869, he succeeded Berthelot as professor of organic chemistry in 1877, after a period of suppléance. At the same time, he was a volontaire at the Collège de France. Presumably Berthelot's closest and most devoted collaborator, since he assumed fully the theories and beliefs of his maître, Jungfleisch succeeded Berthelot in 1908 as professor of organic chemistry at the Collège de France.

4.3- The école

Berthelot portrayed science as a cumulative process of construction developing in time, i.e., he ascribed to science itself a historical dimension:

> We should represent science as a secular edifice which can only be built by the accumulation of huge masses. An entire life of hard-work will be only an obscure stone without a name in these gigantic constructions...The glory of the first explorers is that of being taken over and of giving to the successors the means for them to take over.[142]

This cumulative perspective was also to be manifested in several instances.

Berthelot's research and to some extent that of his école embraced several areas ranging from organic chemistry (1850-1869); physical-chemistry, thermochemistry (1869-1888), agricultural chemistry (1885-1907) to history of chemistry (1885-1907)[143]. Although Berthelot may be considered a positivist, he was to diverge from Comte's own Positivism in some respects. One of them was that Comte considered chemistry still far from the positive stage (1830s), while Berthelot considered that it was close to reaching it, especially after his "invention" of chemical synthesis. This claim, in addition, implied a displacement of the aims of research: if chemistry was near the positive and final stage of its development there was no place either for discovery or innovation, but simply for the reproduction of similar results through the application of the same prescriptions to different objects. Moreover, as regards organic chemistry Berthelot also differed from Comte: Comte considered it as a branch of biology[144], a point which he retained from Romantic science, and Berthelot wanted to reduce it to the rules of mineral chemistry[145]. Moreover, while Berthelot claimed to reject hypotheses and for him experiments were merely a means of collecting huge amounts of observations from which laws could be derived, Comte emphasised the value of hypotheses, which could be verified by experiments, in order to arrive at laws based on observable regularities.

Underlying all his research and that of his école on organic chemistry was an extreme form of empiricism. Thus, he denied the atomic theory[146] and defended a macroscopic approach to the study of chemical compounds based on equivalents. Particularly in his book Chimie organique fondée sur la synthèse (1860) he expressed his views on chemical combinations. Denying atoms and their possible arrangements, Berthelot emphasised synthesis to which he attributed a deep philosophical meaning, and a unifying power within chemistry. But, his ideas of synthesis based on an extreme substantialism only applied to very simple compounds, which merely underwent a single reaction, as for instance, that which occurs between carbon monoxide and steam, under certain conditions, yelding formic acid. According to Jacques[147], Berthelot and his école never tried either to verify a theory, through synthesis (because he did not believe in theories), or determine a structure of a compound because he rejected atoms. His aim was claimed to be philosophical, i.e., he chiefly attempted to show the power of science.

Around 1865 Berthelot changed his research field, moving from organic chemistry to thermochemistry. Thermochemistry was a field which had remained unexplored by the leading

French chefs d'école and therefore enabled him to carve his own place. In this way the rivalry that Berthelot himself considered to have existed between him and Wurtz almost ceased[148], to the extent that their respective research fields were now more differentiated.

Berthelot's thermochemistry corresponded to a reduction of chemical phenomena to the measurement of macroscopic physical parameters and did not consider, like thermodynamics, that a principle of evolution may govern the direction of chemical reactions. His thermochemical concepts proved to be controversial at the time, inasmuch as their author claimed their innovative and insightful character. Especially his principle of maximum work, which the Danish scientist Julius Thomsen[149] claimed to have been the first to formulate in 1853, also provoked strong reactions from Pierre Duhem[150] and the physical chemists Favre and Silberman[151]. Underlying Berthelot's thermochemistry was also the assumption that the quantities of heat were equivalent to the "molecular work" of a reaction, which led him to the formulation of three principles[152], of which the most polemical was the above mentioned principle of the maximum work. This stated that every chemical change accomplished without the intervention of external energy tends to the production of that substance or system of substances which liberates the most heat[153]. This principle, nonetheless, proved not to have the general validity that Berthelot claimed, and notably in the cases of spontaneous reactions which occur with the absorption of heat[154], the occurrence of reversible reactions, and chemical equilibrium. It applied strictly to absolute zero temperature.

From 1885 onwards, Berthelot also engaged in agricultural chemistry, carrying out his research at the Station de Chimie Végétale de Meudon[155] attached to the Collège de France, but again the results obtained were controversial.

The système advocated by Berthelot both in organic chemistry and thermochemistry had to be compulsorily adopted by the majority of his élèves especially because they were paid and were preparing a doctorate under his strict control. His école was, therefore, almost a "factory of doctorates" and in this respect it had no parallel. However, as a serial production, the theses were occasionally seen as repetitive and lacking originality, since one of their main purposes was to reaffirm time and again Berthelot's scientific views. Despite the control imposed by their maître several among the highly-qualified work-force at Berthelot's disposal found ways of preserving their own ideas. This attitude is revealed by situations of both duplicity regarding chemical theory, or by later moves to opposite perspectives. For instance Delépine, in a public competition for a post (1893) used in the written test both atomic and equivalent formulae, fearing that by using atomic weights Jungfleisch, Berthelot's acolyte in the jury, might exert some reprisal[156]. The case of Barbier also provides a further example, since his élève Grignard[157] mentioned that he had trained him according to the atomic theory to which he had adhered enthusiastically, despite the "official" obstacles[158]. Matignon had a similar position to that of his colleagues, and it was he who finally persuaded Berthelot to adopt atomic notation as late as 1891[159].

Concerning thermochemistry similar attitudes occurred, and distinct ideas were expressed even by those who most benefited from Berthelot's patronage. Matignon, who became upon Berthelot's request his suppléant at the Collège de France, moved from thermochemistry to thermodynamics, motivated by his former background in physics acquired at the Ecole Normale[160]. Also Forcrand, another former Normalien did not confine his research to the measurement of heats involved in reactions, but moved to thermodynamics by applying the principle of Carnot to chemical reactions[161]. Taking into account these examples it can be said that, to a certain extent, Berthelot did not have in the long run what the Larousse dictionary refers to as une idée qui fait école for chemical research, which could be spontaneously adopted and later developed by his former élèves.

Berthelot's école never had the control of a journal, but during his scientific life Berthelot himself produced an enormous amount of publications, about 1,600 titles according to Jungfleisch, from which various were intended to be ideological indoctrination. He especially published joint research papers with Jungfleisch and few with his other élèves. Due to the allegations that his élèves devoted several hours daily "to work of general interest" a more detailed analysis would be required to assess eventual intellectual appropriation. As channels for publication Berthelot's école used the usual ones: the Comptes Rendus, the Annales de Chimie and the Bulletin of the Société Chimique. Consistently with his views on science-making, and unlike Pasteur or Wurtz, his articles usually included a great amount of similar data and a great number of details, which themselves emphasised quantity. For instance in his description of the synthesis of alcohol from ethylene, he stressed that the reagents had to be energically and continuously shaken, by going to the detail of indicating with precision 53,000 times, as a condition for a successful experiment. Due to this style, publishing difficulties arose with the Comptes Rendus on account of the excessive length of his papers, which made him invoke his élèves as potential victims of what he understood as the restrictions that the Académie des Sciences was trying to impose on him[162]. He was also accused of publishing the same article several times over and this accusation underlies his quarrel with the editorial board of the Annales de Chimie, when his adversary Wurtz was chief-editor[163].

The involvement of Berthelot's école in a wider context was mainly in the Société Chimique as members, but its intervention in this organisation seems to have mainly been confined to Berthelot himself and not to the école as a group. The participation was very much restricted to the presidency and the intervention in the working posts of the council was very limited: Berthelot was five times elected president (1866, 1875, 1882, 1889, 1901) and his élèves Jungfleisch (1878), Maquenne (1895), Tanret (1897), Riban (1898) once each until the turn of the century.

The école of Berthelot, although having been attended by some foreign élèves, was mainly characterised by being very closed in itself and encircled in the French scientific context, where it could have a more secure existence. Communication with foreign chemists or centres of research was not especially cultivated. Berthelot himself had provided an early indication with his absence from the Karlsruhe (1860) meeting, which had had the presence of the majority of his fellow chefs d'école.

5- Conclusion.

Inspired by the Romantic model of the early 19th century, the movement which led to the establishment of schools was originally an attempt to make research and criticism the very basis of higher education in the German states. However in France, the establishment of the écoles of chemistry in the mid-19th century was an attempt to introduce chemical research in the system of higher education as an officially recognised professional activity. In a word, it corresponded to a process towards the official acceptance of scientific research within universities or similar institutions for higher education, and it was clearly independent from the reforms operated by government in the teaching system. Even the later creation of the Ecole Pratiques des Hautes Etudes was merely the legal accreditation of a situation existing informally.

Progressively moving away from the German Romantic model of the early century, which emphasised the development of personal potentials by incorporating in research creativity and originality explored under the guidance of a master, the whole process of establishing écoles in France was to lead to a normalisation and standardisation of research, methods and ethics. This process, however, went through several stages which presented particular features and also reflected the centralisation practices rooted in the French tradition, especially after Napoleon I. Thus, a review and comparison of the characteristics presented by the écoles of chemistry, regarding organisation, funding, and ideology would make this process clearer.

In order to understand how the the écoles of chemistry were made acceptable and how science had such an appeal as a career to hope for in this period, the ideology transmitted in public language by the scientific community should also be taken into account. Although not uniform the values transmitted present unity and were based on particular representations of science and savant shared among its members. Thus, to science were ascribed two dimensions: a religious dimension and a moral dimension. The religious dimension was acquired either through the association of science with religion (Pasteur) or by replacing religion by science seen as a religion (Berthelot). Both ways it had personal and social ideological implications. At the personal level these implications were manifested by the idea of "martyrdom" which embodied sacrifice and physical suffering, so often mentioned in biographies and even in private correspondence. The social implications were expressed in the idea of apostolate, which implying a service to society embodied the values associated with Motherland and family. As a result of the national awareness, which had resulted from the Romantic Movement, various trends developed throughout the 19th century, and among them either the expression of patriotic feelings or the manifestation of strong and arrogant nationalism erupted, from which science was not immune. Thus, from the ideological point of view the practice of a scientific activity was itself converted in a form of expressing love to Motherland, which had to be passed onto the coming generations. For this purpose the école was presented as a means and the family a model for its organisation. The maître was transformed into a father-like figure guiding his élèves as if they were "sons". These were supposed to continue their work, both by perpetuating what was considered the truth, and at a practical level by inheriting the posts held by their respective maîtres. All was presented as contributing to the glory of France, and thus science with its religious attributes was either above or serving the state.

The moral dimension encapsulated Christian moral values and was portrayed through attributes like seriousness, hard-work and patience, which were converted into components of a new and achievable form of genius. All these virtues ascribed to science and the maîtres-savants, became elements of public discourse in forms such as obituaries and publications on history of science, in which the savants and maîtres were given a place in history. In this way the savants however agnostic, whatever their religious denomination, reached immortality and added to or substituted the accounts on the lives of saints or heros of the past.

This framework of values more than defining an ethical model for individuals infused the very organisation of the écoles of chemistry, which were to reflect them to a great extent. As far as organisation was concerned and beginning with Cahours, the small size of this école portrays an extreme case of the very personal and liberal basis on which this group was established. These were illustrated by the image of a cosy family that faded with the increasing institutionalisation of the écoles. The strongest examples of this type were undoubtedly Cahours and Deville, both former élèves of Dumas, despite the larger scale of the école run by the latter. These family-like patterns, which were particularly evident during Dumas's more influential period, also defined a style of patronage inherent in the paternalistic role of the maître, which followed the similar role ascribed to the Emperor. This protective type of behaviour, which was expected from the maître, covered various aspects ranging from research supervision; publication, to which the maître subscribed as a patron; patronage in relation to careers, particularly the transmission of posts as an heritage in which the eldest élèves had prerogatives of succession; and finally, protection and advice on matters of their private lives. However, this family-like structure acquired progressively other features, which accompanied the change of the political regime in the country, when we move to Pasteur and finally to Berthelot.

The écoles of Cahours and Deville, however, presented already the germ of what was to become an increasing bureaucratization. Particularly, through the establishment of the link between research training and paid teaching activities, as well as the reassurance of a post especially after the completion of a doctorate. With Deville, in particular, this tendency was already strong when the number of doctorates is considered as well as the further posts to which his élèves were appointed in the universities of Paris and in the provinces.

In the case of Pasteur, his indirect role as maître and patron corresponded to a turning point in which the role of the maître became more abstract. Indeed, the disciples, a term often applied in this period when referring to specifically Pasteur's élèves, were to some extent initially following blindly a maître seen in a very ideal way. The organisation of his école portrayed rather the religious family, in which Pasteur occupied the position of a "founder apostle", providing a public image of a disinterested genius devoted to mankind. Having gone through a period of religious debate which culminated during the Third Republic, Pasteur, the Catholic savant, was therefore to follow as a model of organisation for his école the religious one, as portrayed in the foundation of the Institut Pasteur. The Institut Pasteur in Paris, created independently from the Republican government, was to become the centre of his organisation from which his methods and ideals spread through the many delegations opened all over the world with his "disciples". However, this international dimension of Pasteur's enterprise was not a symptom of an ideological position advocating internationalism, but was rather inscribed in the traditions of a French mission civilisatrice. The principles of this mission were represented as charitable and for the sake of humanity, and therefore "Faith, Hope, Charity and Science" irradiated from Paris.

Finally Berthelot, the scientific symbol "canonised" by the Third Republic, personified neither the attentive paternalistic chefs d'école, typical of the Second Empire, nor did he portray the maître like Pasteur. Instead, especially after 1870s, his controlling presence was almost that of a state employer, having at his disposal an administrative and bureaucratic framework. Within this apparatus, the élèves were nearly reduced to the role of civil-servants, who had to accept the regime of the maître without questioning, for the sake of a salary and an almost guaranteed doctorate. Moreover, in this way the doctorate rather than being a part of higher education,was itself bureaucratised. It became rather an initial professional stage, indeed a formality which encapsulated a further academic post ensured by the patronage of the maître.

As regards funding, we may conclude that the launching of the écoles, especially those of Deville, Pasteur and Berthelot depended on the political regime and on the commitment of the maîtres to the regime. Although having Dumas as an intermediate, the creation of the écoles of Deville and Pasteur in the terms in which they were launched, would have been impossible without their personal political acquiescence to the Second Empire. In fact, their research complied with the policies of Napoleon III, who was interested in developing applied science. By providing private funds for both Deville's and Pasteur's laboratories and experiments, the Emperor was himself assuming the role of a patron. These funds were complemented by those occasionally awarded by the Académie des Sciences and the Ministry of Public Instruction, which denoted a funding policy itself based on the traffic of personal influences, i.e., primarily on the patronage of Dumas as an intermediate and that of the Emperor. With Berthelot, the situation changed to a certain extent. Despite the Ecole Pratique des Hautes Etudes having been a creation of the last years of the Second Empire, its results on research emerged more clearly in the framework of the Third Republic. Berthelot and his école were to benefit from funds allocated by the central administration within a specific bureaucratic apparatus created to finance research, officially. Thus, the policy of the Third Republic by encapsulating the écoles in the framework of central administration transformed research into a kind of civil service. However, many of the features of the former policy remained, particularly patronage and traffic of political influences of which Berthelot was, perhaps, the best example. Moreover, unlike the Second Empire, the Republican regime was not so interested in developing applied research, but rather in pure science. Its abstract and inaccessible aura could better serve the Republican ideology in which science was used in propaganda as substitute for religion.

In this context, the école of Wurtz and especially the way in which it was launched and developed represented simultaneously a parallel and an alternative mode of organising research. In the next chapters, the analysis of how Wurtz dealt within and without the scientific establishment, in order to establish his career and his international école will be the central focus of attention.

NOTES TO CHAPTER 1.

1- ETARD, A., "Notice sur la vie et les travaux de Auguste-Thomas Cahours", Bull. Soc. Chim. Fr., 7 (1892), 1-12 (1).

2- Ibid.

3- These type of experiences impregnated of Romantic ideology was a common denominator shared by many men of science in Europe and America throughout the 19th century. The choice of a maître or maîtres to guide personal research, cosmopolitanism, collective publications and travel were some some of the elements of this common ground. See for example the case of Wurtz's élèves, Chapt. 3 and Appendix I.

4- GAUTIER, A., "Biographies scientifiques. L'œuvre de M. A. Cahours", Rev. Sci., 47 (1891), 385-387 (385).

5- As Gautier mentioned, the factor had been the location of both laboratories:

> Le laboratoire du célèbre chimiste était alors rue Cuvier, 24. Du Muséum chez Dumas, il n'y avait qu'un pas. Ibid.

6- See GRIMAUX, E., "Biographies scientifiques. L'œuvre scientifique d'Auguste Cahours", Rev.Sci., 49 (1892), 97-101 (97). Following the method proposed by Dumas and Péligot in their work on methyl alcohol (1839), Cahours obtained a great number of derivatives similar to the corresponding derivatives of ethyl alcohol.

7- A considerable number of letters were exchanged between both chemists, and quite often Gerhardt asked Cahours to be an intermediate between him and Dumas, particularly in Gerhardt's attempts to have a post in Paris with appropriate laboratory facilities. Paris, Académie des Science, Dossier Gerhardt.

8- Notably Grimaux mentioned that Cahours results were still valid 50 years later.

9- The details on Gerhardt's type theory are given in Chapt. 4 of this thesis.

10- Cumul was the accumulation of several posts partly explained by the payment of low salaries to higher education staff in the French educational system, but also had the effect of extending personal or collective control and influence over institutions of higher education, as in the case of the écoles. Among these chefs.d'école Pasteur was the one who most criticised publicly this scheme.

11- Suppléance was substitute lecturing and was closely associated with cumul and patronage. It was a scheme especially used by top professors holding several teaching posts who distributed them, upon payment of a fraction of their salary among their protégés, ensuring in this way their power within the academic system.

12- Like Gerhardt, Laurent had also been an enfant terrible of Dumas.

13 Gautier, op.cit. (4), 386.

14- Etard , op.cit. (1), 6.

15- Notably Cahours was represented as follows:

> La main secourable, l'encouragement sauveur! Cahours fut tout cela pour Etard.
> Ce savant bon et affable...et le conseilla comme s'il eût été son fils.

LEBEAU, P., "Notice sur la vie et les travaux d'Alexandre Etard", Bull.Soc. Chim. Fr., 9 (1911), 1-19 (3).

16 OLIVIER, L., "Alexandre Etard, sa vie et ses travaux", Rev. Gén. Sci. Pur. App., 21 (1910), 581-605 (584).

17- Riche (1829-1908). See HANRIOT, M., "Notice sur Alfred Riche", Bull.Soc. Chim. Fr., 3 (1908), 1-14.

18- Jolyet is only mentioned in Etard, op.cit.(1), 6 and in the list of Cahours's publications, ibid., 11.

19- No mention was found of Pélissard, only a reference in Cahours's, list of publications. Ibid., 11.

20- Few mentions of Gal were found. He probably entered Cahours's laboratory in the 1870s, when they published together studies on phosphorus compounds and arsines. He was awarded the Jecker Prize of the Académie des Sciences, which he shared with de Clermont and Grimaux, both élèves of Wurtz. See Etard, op cit.(1),6. and FREMY, E., (edit.), Encyclopédie chimique, (Paris, 1881), vol.2, p.778.

21- Demarçay (1852-1904). See ETARD, A., "Notice sur la vie et les travaux de Eugène Demarçay", Bull. Soc. Chim. Fr., 32 (1904), 1-7.

22- See Lebeau op.cit.(15) and Olivier , op.cit.(16).

23- See Chapt. 3, Appendix 1 and Chapt. 5, of this thesis. In addition to the obituary written by his élève Etard, the other two obituaries of Cahours were written by Gautier and Grimaux, both élèves of Wurtz.

24 At this time Wurtz was attempting to establish his école.

25- See Chapt. 3 and Appendix 1 of this thesis.

26- The equivalent of a simple substance was the weight of that substance which combines with 100g of oxygen, when its inferior oxide is produced. Thus, the equivalent for hydrogen was 12.50 and for carbon 75. Another version of this same principle was used in parallel and later exclusively, which consisted of dividing all the equivalents by that of hydrogen (12.50). Using this version the equivalent of hydrogen was 1, that of carbon 6 and that of oxygen 8. See Chapt.4 of this thesis.

27- Etard, op.cit. (1), 6.

28- The marginalisation of Gerhardt and Laurent by established figures like Liebig and Dumas partly due to their challenging attitudes, caused some apprehensions in foreign chemists like, for instance, Kekulé who put forward his theory on the structure of chemical compounds cautiously. See Chapt. 4, p. 224, note 203 .

29 Grimaux, op.cit.(5), 101.

30- Unlike Frémy and Pasteur, for instance, Berthelot omitted Cahours from his descriptions of the French chemical scene.

31- Hofmann had also attended Liebig's laboratory in Giessen, where he made a solid friendship with Wurtz. With his French colleagues, Wurtz and Cahours he shared the adoption of Gerhardt's type theory. He was appointed as professor of chemistry at the Royal College of Chemistry in London in 1848, upon Liebig's recommendation.

32 See Chapt.5, section 1.1. of this thesis.

33- Riche and Etard also contributed translations for the Bulletin of the Société Chimique.

34- He shared with Wurtz and Friedel the friendship of Schützenberger and Moissan and of Wurtz's élèves, Gautier and Lecoq de Boisbaudran.

35- The Jecker Prize was given by the Académie des Sciences to reward investigations exclusively on organic chemistry. As a sign of recognition from the Académie des Sciences it was an important step in building up a career, in this period. Cahours had been awarded himself this prize in 1860 and in 1867.

36- See Chapt. 4 of this thesis.

37- Deville previously took two doctorates, one in medicine and another in sciences, both in 1843.

38- Due to Dumas being a catholic Wöhler called him a Jesuit. See PARTINGTON, J.R., A history of chemistry, (London, 1964), vol.4, p.339.

39- See T.H.N., "Etienne Henry Sainte-Claire Deville", Nature, 24 (1881), 219-221 (220).

40- GERNEZ, D.,"Henri Sainte-Claire Deville" in Ecole Normale. Livre du centenaire, 1795 1895, (Paris, 1896), p.421.

41-JOLY, A., "Debray" in Ecole Normale Supérieure. Livre du Centenaire 1795-1895 (Paris,1896), p.426-431 (430).

42- For instance, as Gernez mentioned:

> H. Sainte-Claire Deville, H. Debray et A. Joly...ont porté une vive lumière sur un des chapitres les plus difficiles, les plus pénibles et les plus dangereux de la chimie des métaux.

GERNEZ, D., "Notice sur la vie et les travaux de A. Joly", Bull. Soc. Chim. Fr., 22 (1894), 1-14 (10).

43- See SCHENK, H.G., The mind of the European Romantics an essay in cultural history, (London, 1966), p.15.

44- See SHAFFER, S.,"Genius in Romantic natural philosophy" in CUNNINGHAM, A.; JARDINE, N., (edits.), Romanticism and the sciences, (Cambridge, 1991).

45- BERTHELOT, M., Science et philosophie, (Paris, 1886),p. 243.

46- Quoted from OESPER, R.E.; LEMAY, P.,"Henry Sainte-Claire Deville, 1818-1881", Chymia, 3 (1950), 205-221 (220).

47- The names available for the Normaliens were: Debray, Fouqué, Troost, Fernet, Lamy, Gernez, Lechartier, Isambert, Ditte, Joly, Margottet, Chappuis, Parmentier, Dufet, André, Angot.

48- The non-Normaliens were: Caron (army officer), Grandeau, Hautefeuille, Damour, Cailletet, Clermont, A. Perrey, Baubigny, Zédé (navy officer), Demondésir, Bong, and the foreigners Hiortdahl and Radominsky.

49- As Matignon, élève of Berthelot, emphasised:

> C'est qu'en effet, les élèves de Deville ont occupé pendant longtemps, soit à l'Ecole Normale, soit à la Sorbonne, toutes les chaires de chimie, sauf celle de chimie organique.

MATIGNON, C., "Nécrologie. Louis Troost", Rev. Gén. Sci. Pur. App., 9 (1911), 822-823 (823).

50- This private arrangement did not usually involve work for the doctorate. In fact, only two élèves in this group were detected as having done a doctorate.

51- FIGUIER, L., "Nécrologie scientifique. Henri Debray", L'Ann. Sc. Ind., 32 (1888), 590-593 (592).

52 Gernez mentioned that some young scientists preparing doctorates, notably in natural history and astronomy brought their apparatus to Deville's premises at the Ecole Normale, to perform their experiments. GERNEZ, D., "Notice sur Henri Sainte-Claire Deville, Ann.Sci. Ec. Norm. Sup., 2 (1894), S1-S70 (S61).

53- Debray (1827-1888) was Deville's first élève. He had been appointed agrégé- préparateur in the same year, but before Deville established his research laboratory a the Ecole Normale. He obtained his doctorate in 1855 under Deville's supervision.Between 1857 and 1881 they published jointly about 16 articles. Debray stayed with Deville for 37 years and was elected to the chemistry section of the Académie des Sciences in 1878. He succeeded Deville both at the Sorbonne and at the Ecole Normale.

54 Troost (1825-1911) obtained his doctorate under Deville's supervision in 1857. They published joint papers (about 10), but it was Hautefeuille particularly with whom he published intensively for about 35 years, and in 1884 he was elected to the chemistry section of the Académie des Sciences, on the death of Wurtz. He held a chair at the Sorbonne and was member of the Bureau National des Poids et Mesures, which was set up after Deville's commission to prepare the standard international metre measure. He succeeded Deville as president of the administration of the Parisian Gas Company.

55- Gernez (1834-1910) entered Deville's laboratory in 1860 and stayed with him for about 20 years. In 1897, he was nominated director of the laboratory of the Ecole Normale (until 1904). He expressed the wish that no obituary should be devoted to him. See "Gernez, Désiré-Jean-Baptiste. Titres et publications", Bull.Soc. Chim.Fr., 9 (1911), 1-8. In fact, he had written all the obituaries of his colleagues and of Deville.

56- Joly (1845-1899) took his doctorate in 1877, under Deville's supervision. He held the post of maître de conférences at the Sorbonne (1878), and in 1885 was appointed sub-director of the laboratory at the Ecole Normale on the suggestion of Debray, to whom he succeeded as director in 1888.

57- Hautefeuille (1836-1903). After graduating from the Ecole des Arts et des Manufactures, in 1858, he was recommended by Dumas to Deville. He obtained his doctorate in 1865 under Deville's supervision. Deville nominated him as sub-director of his laboratory at the Ecole Normale, where he stayed for about 30 years. He helped the supervision of some élèves, notably Chappuis, Perrey and Margottet. In 1885, he replaced Friedel as professor of Mineralogy at the Sorbonne, when the former succeeded Wurtz in the chair of organic chemistry. See GERNEZ, D., "Notice sur la vie et les travaux de Paul Hautefeuille" Bull. Soc. Chim. Fr., 29 (1903), 1-20.

58- See LAUDAN, L., Article Comte, D.S.B., vol. 3, p.375-380.

59- Deville hoped that both hypotheses and theories disappeared from science. See Gernez, op.cit.(53), S53.

60- See Chapt. 4, section 2.1.9. of this thesis.

61 See Olivier, op.cit.(16), 596.

62- The Emperor was interested in developing industries and with his support Deville was able to produce on a large scale massive bars of aluminium displayed in the Exhibition of Paris, 1855. A controversy over the isolation of aluminium had been apparently artificially created involving Wöhler. Nevertheless, both chemists worked in cooperation, and through Dumas, Napoleon III made Deville and Wöhler officers of the Légion d'Honneur, simultaneously. See Oesper; Lemay, op.cit. (46),, 211-214.

63- This principle, which explains various apparently abnormal occurrences, may be regarded as the property of several compounds to undergo partial decomposition when heated in confined spaces, until the gas or vapour released had attained a certain pressure, which varies according to temperature. As long as this temperature remains constant, no further decomposition takes place, neither does any portion of the separate constituents recombine. If the temperature increases decomposition starts again and continues until a high pressure of the gas or vapour corresponding to that particular temperature is attained. If the temperature decreases recomposition occurs, until the pressure of the residual gas is reduced to the corresponding lower temperature.

64- See Oesper; Lemay, op.cit., 217. Also Gernez, op.cit (40) and (53).

65 Notably Gautier mentioned that:

> Notre Bulletin contient de lui peu de communications, mais Deville ne manquait aucune de nos solemnités

GAUTIER, A., "Le cinquantenaire de la Société Chimique de France de 1857 à 1907" Rev.Sci., 7 (1907), 641-649 (646).

66- As a patron Dumas acted towards Pasteur in various ways. It was he, who in 1865 asked Pasteur to investigate silkworm diseases, and two years before influenced Napoleon III to commit Pasteur to the studies on wines and vinegars.

67- See DUCLAUX, E., "Le laboratoire de M. Pasteur", in Ecole Normale Supérieure. Livre du centenaire, 1795 1895, (Paris, 1896), p.459.

68- NICOLLE, J., Pasteur, sa vie, sa méthode ses découvertes, (Paris, 1969), p.74.

69- Quoted from FERNBACH, A., "Notice sur la vie et les travaux de Louis Pasteur", Bull.Soc. Chim. Fr., 5 (1909), 1 33 (21).

70- BROOKE, J. H., Science and Religion. Some historical perspectives, (Cambridge, 1991), p.297.

71 D'ESCHEVANNES, C,. Pasteur, sa vie, sa foi, son œuvre, (Paris, 1934), p.192 193.

72- Quoted from DUBOS, R., Louis Pasteur freelance of science, (London, 1951), p.60.

73- Duclaux, op.cit. (68), p.465.

74- GEISON, G.L. , Article Pasteur, D.S.B., vol.10, p.350-416 (385).

75- If Frémy in relation to Deville mentioned, "l'action paternelle qu'il a exercé sur ses élèves", he said nothing of this kind regarding Pasteur. Frémy, op.cit. (20), p.777.

76-"For Pasteur the choice of a collaborator was a matter of little concern, in fact a very secondary thing". Dubos, op.cit.(72), p.60.

77- Duclaux (1840-1904). See DELAUNAY, A., Article Duclaux, D.S.B., vol.4, p. 210-212. He was elected to the Académie des Sciences in 1888.

78 Roux (1853 1933). See DELAUNAY, A., Article Roux, D.S.B., vol.11, p.568-569.

79- Other disciples of Pasteur may be mentioned: Raulin, his first agrégé-préparateur at the Ecole Normale, Thuillier, Viala, Reboud, Fernbach, Chailloux, Borrel, Joubert, Calmette, Marnier, Marie, Loir, Strauss,Veillon, Martin, Nocard, Pottevin, Straus, Wasserzug, Gernez, van Thiegen and Maillot.

80- Chamberland (1851-1908). A Normalien, he entered Pasteur's laboratory in 1875 as agrégé-préparateur. He became an outstanding bacteriologist, especially by the technical improvements he introduced. He remained in the laboratory at the Ecole Normale until 1888,where he created methods of sterilisation of culture media, from which the autoclave has developed. Also the porcelain filter he invented had an immediate use in laboratories, facilitating the discovery of viruses and exotoxins. It had implications for public health, since it applied to the filtration of drinking water. Later (1888) he became director of the laboratory of microbiology applied to hygiene at the Institut Pasteur. He associated another disciple of Pasteur, Fernbach, with his studies on the disinfection of objects and places with hydrogen peroxide and compounds containing chlorine.

81 Thuillier (1856 1883). Also a Normalien, he entered Pasteur's laboratory as agrégé préparateur. In 1881, he was sent to the veterinary institute of Budapest to supervise experiments on public vaccination. With a similar mission he went to Prussia in 1882 and to Egypt, where he died of cholera while he was carrying out a campaign against that disease. In his mission to Egypt he was accompanied by Straus, Nocard and Roux. FIGUIER, L., "Nécrologie Scientifique. Thuillier", L'Ann.Sci. Ind., 27 (1883), 493-494.

82 Calmette (1863-1933). Originally a medical naval doctor, in 1888 he attended the courses on microbiology given by Roux at the Institut Pasteur. At Pasteur's request he was nominated, shortly afterwards, director of a research laboratory in Saigon, where he developed studies on snake poisons. In 1895, he returned to France as director of the Institut Pasteur in Lille. In relation to public health, he is particularly known because of the preparation of anti -tuberculosis vaccine BCG (Bacillus Calmette-Guérin).DELAUNAY, A., Article Calmette, D.S.B., vol. 3, p.22-23.

83- Metchnikoff (1845-1916). He was a zoologist from Russia, who came to Paris in c.1888 to develop his theories on immunology in Roux's laboratory.at the Institut Pasteur.OLIVIER, L., "Nécrologie. Metchnikoff", Rev. Sci. Pur. App., 27 (1916), 497-498.

84 Geison, op.cit. (74), p.376.

85- VALLERY RADOT, (edit.), Œuvres de Pasteur, (Paris, 1922-1939), vol.7, p.209.

86- Ibid., p. 216.

87 Ibid.

88- As Pasteur mentioned:

> En dehors de ses fonctions officielles, le savant, à la rigueur, ne doit rien à l'État. Pourtant il passe sa vie dans son laboratoire ou dans ses collections, au plus grand profit et au plus honneur de tous. Ibid., p.208.

See that although Pasteur considered the possibility of official functions, the rest of the argument is similar to that of Cuvier in his Eloges. OUTRAM, D.,"The languages of natural power: the "Eloges" of Georges Cuvier and the public language of nineteenth century science", Hist. Sci., 16 (1978), 153-178.

89- Pasteur said that:

> What should concern the Emperor are, in my opinion, the living sources of scientific production. Pasteur, op.cit. (85), p.206.

90- Geison, op.cit. (74), p.355.

91- Pasteur became shocked when he was told that at Grancher's laboratory he had two comfortable armchairs, one of them a rocking chair. Grancher was a medical doctor who collaborated in Pasteur's investigations on rabies. Dubos, op.cit. (72),p.62.

92- Pasteur, op.cit. (85), p.200.

93- Duclaux, op.cit. (68), p.468.

94 Duclaux, quoted from Delaunay, op.cit.(77), p. 212.

95- Pasteur was in favour of the Empire and against the Republican regime. That is why he expressed his wish of not being buried in the Panthéon, due to its Republican connotations.

96 Thuillier and Wasserzug are examples of disciples of Pasteur who died while dealing with epidemics.

97- Letter from Pasteur to Roux, 2 September 1885 in VALLERY-RADOT, Correspondance de Pasteur, 1840-1895, (Paris, 1951), vol. 4, p. 36.

98- Fernbach, op.cit. (70), p.1.

99 See LATOUR, B., The Pasteurization of France, (Cambridge Mass., 1988), p.68, and Nicolle, op.cit. (69), p.95.

100 Geison, op.cit. (74), p. 351.

101 The experiments on fermentation began in a provisional laboratory set up by Duclaux and were repeated on a larger scale at the Kuhn brewery. They were intended to tackle a crisis in the brewing industry.

102 For instance Pasteur's studies on vaccines and fermentations led to the development of immunology by Metchnikoff, and of biochemistry by Duclaux, as well as of bacteriology by Roux and Calmette.

103- Geison, op.cit. (74), p.355.

104- Duclaux made the following remark:

> Mais si M. Pasteur se livrait volontiers aux oreilles amies, il avait l'epiderme sensible vis-à-vis les critiques. Duclaux, op.cit. (68), p.461.

105- BROOKE, J. H.,"Organic synthesis and the unification of chemistry-a reappraisal", B.J.H.S., 5 (1971), 363 392 (366).

106- Duclaux, for instance considered a chemical approach in medicine as absolutely indispensable:

> Avec Pasteur la chimie prendrait possession de la médecine. On peut prévoir qu'elle ne la lachera pas.

DUCLAUX, E., Pasteur, l'histoire d'un esprit, (Paris, 1896), p.395.

107 Pasteur wrote on this occasion to the Académie des Sciences, saying:

> Le jour ou une chaire de chimie organique sera créé, si j'en ai la liberté je la réclamerai instamment comme un droit, je me porterai candidat.

JACQUES, J., Berthelot. Autopsie d'un mythe, (Paris,1987), p.66.

108- Duclaux, op. cit. (68), p.461.

109- Notably, according to the description of Madame Didier, who ran a salon that Berthelot attended :

> Sa mère est très dévote, très catholique. Elle l'a tenu dans sa plus sévère dépendance. Ce joug a pesé sur lui jusqu'à vingt ans. Il s'appartient à peine aujourd'hui qu'il en a trente-deux, il n'est guère émancipé que sur le chapitre du libre examen.

Quoted from JUNGFLEISCH, E., Notice sur la vie et les travaux de Marcellin Berthelot, (Paris, 1913), p.21.

110- Ibid., p.20.
Previously Berthelot registered in the Faculty of Medicine in 1848, but he gave up in 1850. However, in 1849 he obtained his licence in physical sciences from the Sorbonne. He was to obtain his doctorate (1854) and in 1859 after attending the courses at Faculty of Pharmacy, he obtained his degree of 1st class Pharmacist.

111- " Sur la création d'une chaire de chimie organique au Collège de France", Journal Général de l'Instruction Publique, 26 December, 1863.

112- As the newspaper mentioned:

> La place légitime de M. Berthelot est marqué depuis longtemps dans l'enseignement du Collège de France, au jugement des hommes compétents, et par la nature de son talent comme de ses découvertes. C'est là qu'il peut servir le plus utilement son pays, en communiquant à la jeunesse les connaissances qu'il possède et le zèle dont il est animé. Ibid.

113- The signatures were in this order: Balard, Claude Bernard, Bertrand, Serret, Flourens, Liouville, Stanislas Julien, Dumas, Michel Chevalier, Pelouze, Rayer, Deville and Regnault.

114 Pasteur argued:

> Quoiqu'il en soit, tant de motifs graves militent en faveur de ma façon de voir que je ne puis me faire à l'idée que votre signature a été donné sans que vous avez conservé des scrupules au sujet de votre affaire. A tous les points de vues je suis surpris. Quoted from Jacques, op.cit. (107), p. 67.

Dumas's signature may be partly understood in the context of the concessions implied in his powerful position, particularly regarding his colleague Balard, the former maître of Berthelot, since all the other posts in institutions for higher education had been taken by his own former élèves. Another possible reason is that Dumas himself had been influenced by Comte and Positivism.

115- The conspiracy was in Pasteur's words:

> Je ne vois dans tout ceci qu'une des manifestations de cette école, impatiente et dangereuse, personifié dans les noms de MM. Renan, Taine, Littré et c'est Renan qui a fait la chose et qui a eu l'habilité de la faire signer par les membres de l'Académie des Sciences. Ibid., p. 68.

116- It seems that Wurtz and Dumas had a previous arrangement, according to which Wurtz would be allocated a research laboratory at the Collège de France, since what he had at the Faculty of Medicine was not considered adequate to the volume of research of his école:

> Depuis que j'ai eu l'honneur de vous entretenir au sujet de la chaire de chimie au

Collège de France il s'est passé un fait très grave; la Note réccement adressé au Ministre qui a été insérée dans le Journal de l'Instruction Publique.

Letter from Wurtz to Dumas (30/12/1863). Paris , Archives de l'Académie des Sciences, Dossier Wurtz.

117- He also argued that:

> Les signataires de la Note ont perdu de vue les droits et les interêts légitimes d'autres savants parmi lesquels il m'est permis de me compter. Ibid.

118- Berthelot was displeased with the petition, because it had a note added by the ministry saying that despite the claim about Berthelot, other chemists were free to present their candidacies. In addition, he was displeased with his provisional appointment and wrote to the minister of education Duruy:

> Je regrette que vous vous soyez cru obligé d'ajouter une note qui enlève à l'arrêté que vous aviez bien voulu prendre à peu près tout ce qu'il y avait de flatteur et d'avantageux pour moi. Quoted from Jacques, op.cit. (107), p.69.

119- In fact the Faculty of Pharmacy did not have great prestige, and often had to fight for demarcation. especially against medical doctors and the Faculty of Medicine, which were determined to keep their supremacy. That may explain Berthelot's interest in the Collège de France, which provided him with a higher status.

120-As regards the Académie des Sciences, Berthelot failed three times in elections for a place in the section of chemistry and he did not enter that institution until 1873. The first attempt was in 1857, when Frémy was elected. The second was in 1867 in the death of Pelouze, but Wurtz was preferred. He tried again in 1868, but Cahours was chosen. In these two last attempts, he lost the election to two of Dumas's former élèves. Later in 1873, owing to Duhamel's death a vacancy occurred in physics section. As Berthelot had done research in physical-chemistry, his friends (according to Jungfleisch) presented him as a candidate. Even in the third position of the list drawn up by the physics section, as equal with other nine candidates, he was finally elected. In 1889 he became lifelong secretary of the Académie, when Pasteur retired. By this time Cahours, Deville and Wurtz were all dead.

121- Renan (1832-1892). Historian and philologist, who in 1862 held the chair of Hebrew at the Collège de France. Since Berthelot was fourteen years old, they were close friends and influenced each other. Renan, essentially a Romantic figure, became agnostic in 1845 and owing to his "subversive" principles his courses at the Collège de France were abolished until 1870. In this same year, he succeeded Claude Bernard in the Académie Française.

122- The Goncourt brothers started by being impressed by Berthelot, but later they revealed their disappointment. See Jacques, op.cit. (107), p.57.

123 Jungfleisch, op.cit. (109), p.26.

124 As Berthelot said of himself:

> J'ai eu l'art de tirer des hommes tout ce qu'il peuvent donner.

Ibid.

125- Delépine (1871 1934), became professor later at the Collège de France.

126- DELEPINE, M., (Announcement of Matignon's death), Bull.Soc. Chim. Fr. , 1 (1934), 467-476 (469).
Matignon (1867 1934). A former Normalien , he stayed for four years with Berthelot, with whom he did his doctorate. In 1893, he was appointed to the Science Faculty of Lille. He succeeded Joly in the Sorbonne in 1947, and became Berthelot's suppléant for the chair of organic chemistry at the Collège de France (1898). He was appointed Professor of mineral chemistry at that institution , when Jungfleisch succeeded Berthelot. BOURION, F., "Notice sur la vie et les travaux de Camille Matignon", Bull.Soc. Chim. Fr., 2 (1935), 377-427.

127- GODCHOT, M., "Robert de Forcrand", Bull.Soc. Chim. Fr. , 1 (1934), 1-30 (2).

128- During the Franco-Prussian war, the Comité Scientifique pour la Défense de Paris was created and Berthelot was appointed the president. The contacts he established during this period with politicians may be regarded as the origin of his political career. He started in administration as Inspector for Higher Education (1876-1888), followed by his nomination as member of the Council of Fine Arts in 1880. Afterwards, he was appointed Minister of Education between 1886-1887 and Minister of the Foreign Office between 1895-1896, under the pretext that he was member of several foreign scientific organisations. As Inspector for Higher Education, Minister of Education, and secretary of the Académie des Sciences, Berthelot had a major role in hindering the teaching and usage of atomic theory, which according to Haller had a negative effect on French chemical industry. Jacques, op.cit. (107), 202-206.

129- Outram, op.cit. (88).

130- See BERTHELOT, M., Science et Philosophie, (Paris, 1886), p.2.

131- Quoted from Jungfleisch, op.cit. (109), p.14.

132- See Jacques, op.cit. (107), p.260.

133- See Paris Médicale. Assistance et Enseignement, (Paris, 1900), 175-180.

134- At the Faculty of Pharmacy the préparateurs du cours only committed to teaching duties, were: Personne, Jungfleisch, J. Curie, Prunier, Ogier. Some of these and others attended Berthelot's research laboratory, helping him in his research as volontaires. Among them were: Lorrain, Jungfleisch, Bourgoin and Prunier.

At the Collège de France the préparateurs du cours only implied officially teaching duties, although as volontaires they could carry out research were: Lorrain 91864--1865), Amagat (1865-1866), Barré (1866-1869), Bouchardat (1869-1874), Barbier (1874-1875), Ogier (1874-1882), Forcrand (1882-1884), André (1884 1885), Brasse (1885-1890), Tassily (1890-1895), Delépine (1895-1902) and Trannoy (1902-1907).

The préparateurs of the research laboratory belonging to the Ecole Pratique des Hautes Etudes at the Collège the France were: Sabatier (1878-1880), Joannis (1880-1882), Guntz (1882-1884), Recoura (1884-1887), Petit (1887-1889), Matignon (1889-1892), d'Aladern (1892), Lemoult (1892-1897), Valeur (1897-1898), Leroy (1898-1900), Bouzat (1900-1903), Landrieu (1903-1907). The préparateurs -adjoints were: Holaing (1881-1882), André (1881-1885), Varet (1885-1896), Montreuil-Jacquart (1896-1897), Trannoy (1898-1902), Bonnameaux (1905-1907), Gallois (1904-1905), Humbert (1905-1907). Finally among the volontaires were: Villiers, Richet, Tanret, Allain-le-Canu, Richard and Fabre. Between 1865-1907, foreign volontaires attended the Collège de France. Their names and nationalities were: G. Werner, Bredig, Stohman (German); Fogh (Danish); Calderon (Spanish), Ilosway (Hungarian); Brunner (Polish); Luguinin, E. Werner, Ossipoff, Timiriazeff, Tscheltov (Russians); Schmidlin, A. Werner (Swiss). See Jungfleisch, op.cit. (109), 26-27.

135- Delépine op.cit (126), 468.

136- Guntz (1859 1935). Of Alsatian origine he graduated from the Ecole Normale, where he became friend of Jaurès and Bergson. Later in 1890 with Haller he collaborated in the foundation of the Institut de Chimie of the University of Nancy. See HACKSPILL, L., "Notice sur la vie et les travaux de A. N. Guntz", Bull.Soc. Chim. Fr., 4 (1937), 372-390.

137- Thus,

> Guntz, s'il avait suivi son penchant naturelle , fut devenu un disciple de Pasteur; mais il fallait pour cela entreprendre de longues études médicales et imposer ainsi à ses parents peu fortunés un nouveau sacrifice. C'est ainsi qu'il fut amené à accepter un poste d'agrégé-préparateur offert par Berthelot. Le traitement était des plus médiocres mais il s'ajoutait la possibilité de préparer une thèse de doctorat sur un sujet de thermochimie. Ibid., 374.

138- Sabatier (1854 1942). Agrégé of physics at the Ecole Normale (1877) he obtained his doctorate with Berthelot in 1880. Despite having passed, his thesis was considered as lacking originality, notably by Deville (member of the jury). Then he moved to the Faculty of Science of Toulouse, where he fully engaged in the foundation of the Institut of chemistry. In 1912, he was awarded the Nobel Prize for his studies in catalysis. Corresponding member of the Académie des Sciences he always refused to return to Paris. He was a catholic and ideologically he claimed to be closer to Pasteur and Poincaré. See NYE, M.J.,"Nonconformity and creativity; a study of Paul Sabatier, chemical theory and the French scientific community",Isis, 68 (1977), 375 391.

139 Ibid., (377).

140 Hackspill, op.cit. (136), 374.

141- Jungfleisch (1839 1916). Of Alsatian origin, he became member of the Académie des Sciences in 1909 in the chemistry section at the death of Ditte, Deville's élève. His investigations were mainly devoted to organic chemistry. He collaborated in Berthelot's Traité de chimie fondée sur la synthèse, which he continually revised for its successive editions.

142- Berthelot in L'Avenir de la science. Quoted from Jungfleisch, op.cit. (109), p.11.

143- His élèves did not engage in this line of historical research. Berthelot wrote especially on Alchemy. This work was framed in the law of the three stages of Comte, which he did not acknowledge, and had a pedagogical function for chemists not to engage in the mystical trends of the past. He also developed methods for the chemical analysis of archeological materials. see CROSLAND,M., Article Berthelot, D.S.B., vol.2, p.62-72. See also Berthelot's Les origines de l'alchimie (Paris, 1885) and La chimie au moyen age (Paris,1895).

144- See COMTE, A., The positive philosophy (transl.) (N. York, 1974), p.298.

145- See Chapt.4 of this thesis.

146 He denied the atomic theory. His main criticism was that recent theories of organic chemistry were based:

> almost exclusively on the combination of signs and formulae. They are theories of language not theories of facts. See Jacques, op.cit. (107),p.73

See also Chapt. 4, section 2.1.9. of this thesis.

147 Jacques op.cit. (107), p.77.

148- Berthelot acknowledged his rivalry with Wurtz. See Berthelot, op.cit. (128). p.251.

149- Thomsen in 1873, manifested his indignation regarding Berthelot, by saying that he expected:

> qu'avec le temps celui-ci finirait par se mettre au courant de la bibliographie. Jacques, op.cit. (107), p.139.

150- See DOLBY, R.G.A., "Thermochemistry versus thermodynamics: the 19th century controversy", Hist. Sci., 22 (1984), 375-400.

151 As Favre and Silberman argued:

> Si l'habile professeur s'est trouvé en mesure de donner des leçons, c'est parce que nous lui avions fourni les nombres nécessaires aux calculs et aux idées fondamentales. Jacques, op.cit.(107), p.139.

152 The two first principles stated that:
1- The principle of molecular work: the amount of heat liberated in any reaction measures the sum of chemical and physical changes accomplished in the reaction.
2- The principle of equivalence of chemical transformations: the quantity of heat liberated or absorbed owing to chemical transformations depends only upon the initial and final state of the system under consideration. It is independent of the sequence or nature of intermediate states, whatever they might be.

153- According to Berthelot work was identified with the heat of a chemical reaction, which was seen as being equal to the decrease of the total energy of a system and affinity as the resultant of the actions which hold together the elements of compounds. See SCHELAR, V., "Thermochemistry and the third law of thermodynamics", Chymia, 11 (1966), 96-124 (113).

154 Favre and Silberman also disproved the general validity of the principle of maximum work. In the mid 19th century, every exothermic reaction was regarded as combustion, whereas every decomposition was

envisaged as endothermic. They have shown that nitrous oxide decomposes into nitrogen and oxygen, liberating heat.

155- This institution was funded by both the Ministry of Agriculture and of Public Instruction.

156 See Jacques, op.cit. (107), p.32.

157 Grignard (1871-1935) was awarded the Nobel Prize of chemistry in 1912. He had been élève of Barbier (1848-1922).

158- See Jacques, op.cit. (107), p.27.

159 As Matignon mentioned:

> Je lui (Berthelot) fait remarquer respectueusement qu'il serait plus logique de faire emploi du language adopté par la majorité des chimistes. C'est à la suite de cette conversation que je présentai à l'Académie des Sciences, le premier travail sorti du laboratoire de Berthelot avec les formules atomiques.

COLMANT, P.,"Querelle à l'Institut entre les équivalentistes et atomistes", Rev. Quest. Sci., 143 (1972), 493-519 (519).

160- See Bourion, op.cit. (126), 380.

161- See Godchot, op.cit. (127), 23.
Forcrand (1856-1933) did his doctorate with Berthelot. He moved later to Montpellier and contributed to the foundation of the Institut of chemistry.

162 In a letter to Dumas (18 April 1882), Berthelot expressed his complaints about the restrictions imposed by the Académie on the length of his articles in the following terms:

> La parole me sera-t-elle retirée, au moment même ou se développe le mouvement scientifique que j'ai soulevé. Au moment ou ma production personelle aidé de celles de mes élèves que j'ai réussi lentement à former autour de moi atteint tout son activité?

Paris, Archives de l'Académie des Sciences, Dossier Berthelot.

163- In 1872, Wurtz was chief-editor of the Annales de Chimie and refused to publish some articles of Berthelot. The latter wrote to Dumas, the former chief-editor, complaining:

> mais ce qui m'a engagé à vous écrire, c'est pour réclamer contre ces retards, ces renvois, ces procédés sommaires.

Paris, Archives de l'Académie des sciences, Dossier Berthelot (letter sent on 23/1/1872).
On the other hand, Wurtz also sent a letter to Dumas focussing on the same matter and expressing ironically his criticisms:

> J'ai écrit à Berthelot pour lui faire savoir que la Commission des Annales s'était interdit de la reproduction de textes déjà publiés, et qu'elle le priait, en conséquence, de modifier les sens de façon à leur donner un tout original. J'ai ajouté que nous serions heureux de les publier de cette forme rajeuni.

Paris, Archives de l'Académie des Sciences, Dossier Wurtz (letter sent on 26/1/1872)

CHAPTER 2 - ADOLPHE WURTZ (1817-1884), THE MAITRE: HIS PORTRAITS, HIS BIOGRAPHY, HIS IDEAS.

1- His portraits.

It is now time to focus on Adolphe Wurtz and the aim of this section is to present how Wurtz was seen and described in public language in different dimensions of his life by his contemporaries, both élèves and colleagues, the majority of these descriptions being taken from several posthumous eulogies. In the period under consideration the eulogies of savants were written according to a particular style whose chief goal was to present the deceased as a moral model in several aspects of his life, and thus the descriptions of Adolphe Wurtz are no exception. However, his portraits were often painted with different colours from those of the other chefs d'école , projecting in this way a peculiar image. The descriptions of his character seem therefore to be the result of two distinct factors: on the one hand, they were conditioned by the personal values of those who described him, on the other, Wurtz himself built up a permanent image, which was based on particular patterns that the Parisian chemical community did not share to a great extent, but had to come to terms with.

As a general feature he was never represented either by himself or by others as a "martyr" of science consumed by overwhelming work[1]. On the contrary, unlike Pasteur who was said to be serious and unable to laugh[2] Wurtz was commonly represented as a happy man, enjoying his life and work[3]. Moreover, references to his physical features often appeared in his eulogies. Unlike in those of his colleagues, the description of their personal appearance was almost completely replaced by features of moral order. In fact, one of the striking characteristics of the majority of descriptions of savants was that they were represented as if they were bodiless. Practically, there are no descriptions of their physical peculiarities and when these were mentioned they merely account for physical suffering, usually attributed to excessive commitment to their research.

Many portraits of Wurtz were produced, representing him in several places and on different occasions. Usually, in this period, one of the aspects that biographers accounted for was the relation between the singularity of a particular character and a geographical region that could or could not relate to his specific geographical origin. Indeed, human behaviour and features were dealt with as if they had a precise location in a chart[4], denoting a particular awareness of national and regional peculiarities, and thus the singularity of a character was associated with the singularity of a region. In Wurtz's case he had been born in Alsace and educated according to the local Protestant tradition. His adversary Berthelot, in his eulogy of Wurtz, claimed in the Romantic literary fashion that he represented the particular genius of his home region:

> Wurtz had been one of the most brilliant representatives of this fortunate alliance between the Gallic and Teutonic genius...he portrayed the moral alliance of these two races not only by his birth, but also by his education, ideology and even by his discoveries.[5]

This different background, however, which for Berthelot was consistent with his rival's particular conduct as <u>savant</u>, intrigued Wurtz's colleague Dr. Henri Gregor. He provided an image of Wurtz while lecturing at the Faculty of Medicine, in which he emphasised Wurtz's unusual exuberance with the remark that it was more compatible with someone born in Bordeaux or Marseille than in Strasbourg[6]. From his testimony and others[7], Wurtz's image was that of a man "always straight, supple, alert and robust"[8] in the lecture theatre of the Faculty of Medicine, keeping his audience

> suspended from his lips, his eyes, his arms, all his figure, which was lively and active, ardent and restless. All his body communicated expressively to the highest degree.[9]

But if the lecture theatre is a place requiring performing abilities, given its spatial dimension and audience, this same exuberance was described by his <u>élèves</u> in their daily contact with Wurtz in the research laboratory:

> His face of regular features was mobile and lit up by a straight and lively way of looking, which captivated his <u>élèves</u>.[10]

These descriptions of his abilities for communication were often associated with Wurtz's artistic tastes mentioned in several sources. As a result, other particular dimensions were added to Wurtz's image, particularly those of amateur of music and sportsman. Unlike Berthelot, to whom music was a waste of time because it lacked seriousness[11], Wurtz cultivated music and was an amateur singer. In this respect he was closer to the Romantic German tradition from which the association of music, considered the art par excellence, and science was to be revealed by many German scientists . Thus, Wurtz and some of his élèves used to sing while working in the laboratory[12], and according to his fellow Alsatian Haller:

> Thanks to his happy character and to his artistic nature, Wurtz was often asked to participate in those gatherings in which students and amateurs used to meet and enjoy art. Having a beautiful voice of baritone, Wurtz was an expert and a passionate amateur of music.[13]

But a facet of sportsman was added to his image, which did not find any parallel in other chefsd'école and was nonetheless emphasised by his colleagues and élèves[14]:

> He had always liked to exercise his body: long walks, fishing (fishing was something surprising in a man almost unable to be motionless), swimming, gymnastics, which he practiced regularly until his death.[15]

These same pictures of sportsman and amateur musician applied to many of his élèves as it will be seen in due course[16] and particularly those of Alsatian extraction, who were living in Paris, shared with him some of these leisure activities[17].

In the laboratory while working side-by-side with his élèves Wurtz was not portrayed either as a typical paternalistic figure like Cahours or Deville, nor as a distant leader like Pasteur, nor even as an implacable and bureaucratic maître like Berthelot. His representations are rather those of a more experienced colleague, who was able to accept the opinions of his élèves and the limits of his knowledge[18]:

> All these new theories[19] were evolving at the time. We discussed them among ourselves and with Wurtz, who while making his own points, was ready to listen to those of us who possessed more specialised knowledge of certain techniques, or of physics, mechanics, mineralogy or biology[20]

As a chemist he came to be seen as the leading advocate of atomic theory in France which, with the exception of Cahours, was by no means accepted by his more direct adversaries. They basically claimed that atoms were not facts, but products of language and imagination[21], and in association Wurtz was also seen as responsible for the introduction of barbaric words (organic nomenclature) in the French language:

> The French language has against Wurtz and his école an important grievance: it is the fabrication of barbaric and endless words often

> with more than 15 syllables, which are similar to those of botanical nomenclature, before Linnaeus's reform. When shall we have the Linnaeus of atomic theory?[22]

For his élèves, however, this was not a stumbling block, and Gautier, who did not share the metaphysical implications of Wurtz's atomism, dared to emphasise an image of Wurtz as a metaphysician:

> The essence of Wurtz's work is metaphysical. For him the purpose of the chemist was to demonstrate lucidly and precisely the ideas of the metaphysician about the general composition of the world. The atomic theory was established definitively by him and his remarkable laboratory expertise, which underlies so many discoveries, and was only carried out to establish and consolidate his concepts about matter and about the architecture of the world.[23]

Ideologically, Wurtz was seen as "a friend of individual initiative, not only in theory but in practice"[24], but from the political point of view he was described as a "conservative Republican"[25], who respected authority and legal order[26].

As a religious man, belonging to the Alsatian Confession of Augsburg, he was portrayed as an active member, who devoted some of his time to religious causes [27]. Participating in the reorganisation of the Faculty of Theology of Strasbourg and a member of several Protestant synods, his activities were described as carried out "in an open and practical way"[28]. Friedel gave of him a portrait of a man who easily allied science with religion:

> The alliance between science and religion is often considered a chimera, Wurtz knew that it was possible through his personal experience...he knew its implications: science makes religion more human and religion gives to science wings to fly towards the ideal.[29]

According to the tastes of the time Wurtz, like his colleagues, was described as a "hero" with a place in history. However, he was portrayed as a distinct type of hero, and if this happened with the descriptions of his life it also happened with his death. Unlike Pasteur, whose death was attributed by some to excessive work[30], or Berthelot, who Romantically was claimed to have been unable to survive his wife, dying some hours later[31], Wurtz's death was portrayed as more mundane[32] and perhaps more consistent with his image when alive. However, the editor Figuier, presented Wurtz as a man who died from ambition:

> We, his friends, often advised him to restrain his ambitions. He was eager for posts and as he was conscientious and wanted to respond fully to all his obligations, he was victim of this misfortune.[33]

However laudatory the descriptions of Wurtz, they provided some clues about this French maître, enabling us to understand to what extent and in the name of what values he was considered a model, i.e., someone worth imitating. His biography, in addition, is to give us a clearer picture of his personal process and of the way in which he interacted and modified his share of history in his time.

2- His biography.

2.1.- Background and career until 1853.

Charles -Adolphe Wurtz was born at Strasbourg (Alsace) on 26 November 1817[34]. His father Jean-Jacques Wurtz, who was the Protestant minister of Wolfisheim, a village near Strasbourg, is described as possessing a considerable culture, but a gloomy disposition. His mother Sophie Kreiss, who had apparently a strong influence on his son's character, is described as joyful, lively and sweet-tempered.

Wurtz spent his early childhood in Wolfisheim, but in 1826 his father was appointed to the church of Saint-Pierre-le-Jeune at Strasbourg, where Wurtz entered[35] the Protestant Gymnasium. The Lutheran Gymnasium of Strasbourg was an ecclesiastical secondary school with long traditions, which had been founded by Jean Sturm[36] and belonged to the Augsburg Confession. It was a highly regarded institution, which had been able to preserve its heritage, notably from the several attempts from the Ministry of Education to convert it into a lycée[37]. Although independent, it had been linked to the Protestant Faculty, which in the previous century was more prestigious than the Catholic, attracting many European students and professors[38]. Thus , unlike his Parisian colleagues, Wurtz did not follow the usual steps of a French formal education. Like the majority of the Alsatian bourgeoisie, he enrolled in a Gymnasium, hence benefiting from a bilingual teaching, which integrated science, music and physical education. During the eight years of his secondary education, however he did not distinguish himself, which led his father to conclude that he would never do anything worthwhile in his life[39].

Since his childhood in the countryside, and while carrying out his studies in the Gymnasium, Wurtz was especially influenced by his uncles Théodore and Adolphe Kreiss[40], who greatly contributed to his intellectual development and encouraged him throughout his scientific studies. Thus in 1828, he enroled on voluntary basis in a course on botany, which awakened him an interest in Natural History. Moreover when he was already fully engaged in chemical research, he still read with interest[41] the work of the German Naturphilosoph Lorenz Oken (1779-1851), a protégé of Goethe. Oken who developed the theory of the ideal vertebrate archetype within transcendental anatomy[42], had founded the Gesellschaft Deutscher Naturforscher und Aerzte, an association which became a paradigm for other peripatetic scientific organisations throughout Europe like, for instance, the British Association for the Advancement of Science.

In 1834 Wurtz passed the exam of bachelier ès lettres and left the Gymnasium. His father wanted him to study theology, but Wurtz already expressed a wish to pursue studies in science. With his mother's approval but scepticism and even opposition from his father, he began doing physical and chemical experiments in the laundry of his parent's house. His inclination for chemistry had been awakened by his visits to dyestuffs and textile industrial plants in the region[43], and was fostered by his friendship with Emile Kopp[44], who later himself became a chemist and collaborated in Wurtz's Dictionnaire de chimie. As his father refused him permission to engage formally in chemical studies he enroled in the Faculty of Medicine at Strasbourg. The Faculty of Medicine was one of the Alsatian Faculties where intense political and religious controversies took place, especially between Protestants and Catholics. These involved in the 1820s relatives of some of the Alsatian élèves, who later were to attend Wurtz's research laboratory[45].

His decision to follow medicine was taken because Wurtz foresaw the possibility of access to chemistry courses. In 1835 he became aide-préparateur in the Department of Pharmacy and in 1839 he was appointed chef de travaux chimiques to Professor Cailliot, to whom he would later offer the hospitality of his laboratory in Paris (1870s), when Alsace was annexed to Prussia. He took the doctorate in medicine in 1843 with a thesis entitled Essai sur l'albumine et la fibrine, which gained him a medal from the Faculty. He then obtained support from his parents to go for a year to Liebig's laboratory in Giessen where he made close friendships with Hofmann, Strecker[46], and Hermann Kopp[47]. Liebig meanwhile entrusted Wurtz with the translation of his research papers into French, as he had done before with Gerhardt (1836-1837). These translations were to be published in the Annales de Chimie and proved to be rather important, since they brought Wurtz into contact with several leading French chemists including Dumas.

Wurtz's departure to Giessen had marked his physical separation from Alsace, but not his divorce from many of the features of the inhabitants of his home region. Despite being a heterogeneous province in which religious diversity implied political diversity, Alsace also presented linguistic, religious, political and economic peculiarities, which demarcated it from the rest of French provinces, and of which its inhabitants were extremely conscious. From the religious point of view while the Reformation had introduced a bourgeois way of understanding religion, French sovereignty introduced in Alsace a double differentiation - religion and language. In fact, Alsace had been German during the Reformation, but had become French before the period of the French Revolution. However and above all, it had been and was still in the 19th century, religion which shaped mainly the Alsatian lifestyle[48]. From the religious point of view, Alsace, in addition to a Catholic and a small Jewish minority, had three major Protestant groups: the Calvinists, especially located in the industrial region of Mulhouse, the Lutherans of the Confession of Augsburg of Alsace-Lorraine, whose consistory was in Strasbourg, and finally the Reformed Church of Alsace-Lorraine.

Wurtz had been brought up and belonged for his entire life to the Augsburg Lutheran denomination. Generally the Lutherans in Alsace were traditionally considered wealthier and more educated than the other inhabitants of the region[49], but those of the Augsburg Confession, belonging to the bourgeoisie were regarded as members of an elite, the Eglise des Notables[50]. As a general feature of the Alsatian Protestantism it is claimed that it associated flexibility with a deep sense of practicality[51]. This sense of practicality contrasted with the French traditional centralisation practices, and was illustrated by their independent way of solving local problems, which materialised in the proliferation of religious, cultural and economic societies, whose aim was to defend the interests of the several groups. As a result of the national and regional awareness generated from the Romantic Movement and of its repercussions in the social realm, Alsace saw during the 19th century a widespread proliferation of associations which extended to the level of the working classes, who joined in mutual improvement societies for savings, health, education, etc., giving a dimension of the industrious and industrial commitments of this particular province. Among these societies, the Société Industrielle de Mulhouse, to which Wurtz was later to belong, should be mentioned, due to its influential role in Alsace, notably for the development of technical education, applied research and associated publication.

From the economic point of view, Alsace had a powerful industrial activity, particularly as regards brewery, textiles, dyestuffs, painted paper and related machinery. One of the most important centres was undoubtedly Mulhouse. Here industry was in the hands of some influential families, who kept their wealth and traditions, notably through a system of intermarriage, in which, industrialists, scientists and clergymen shared a similar social status. It is claimed that these families "extracted from their wealth as much pride as the aristocracy of the ancien régime extracted from their noble titles"[52] and that they practiced religious tolerance[53]. Many of these features and practices are to be found in the many élèves of Alsatian extraction, who were to belong to Wurtz's école[54]. The concern with education was also striking and materialised in the foundation in 1822 of the Ecole de Chimie de la Ville de Mulhouse, which provided technical training. This school eventually inspired the creation of the Ecole Municipale de Physique et de Chimie Industrielles de Paris, founded in 1882, with the participation of some of Wurtz's élèves[55] and Alsatian friends.

In the 19th century, the Calvinist industrialists of Mulhouse were a part of a regional elite together with other Protestants of Alsace, notably the Lutherans. This elite was defined not only in economic terms, but also culturally. They maintained and advocated interactions with countries[56] such as Switzerland and the German states to which they were linked by language, culture and religion, but also with Russia and Great Britain with which they had economic interests and some religious dialogue.

Throughout the 19th century the Alsatian elite linked together certain Romantic values which were epitomised in a kind of regional ideal. This ideal advocated in an integrated manner, the association of good administration of wealth with social concerns regarding the working classes, the development of science, political economy and statistics, and the cultivation of music and art[57]. These were basically some of the features and ideals of Wurtz's home province, and his departure from home to Giessen itself can be envisaged as framed in those ideals. Many of these still Romantic trends were to be shared not only with his Alsatian élèves, but also with the majority of the foreigners who were to attend his laboratory, especially those coming from the German states, Austria and Russia or other territories under more direct German cultural influence.

After his stay in Giessen, Wurtz went on a short trip to Vienna and then returned to Strasbourg (1844) for a while, with some letters of reference from Liebig. In March of that same year, Wurtz wrote to Dumas[58] introducing himself and reporting on his recent investigations. He let Dumas know about his intention to go to Paris, and he mentioned that his contract as préparateur of the Faculty of Medicine of Strasbourg was about to end, which suggests an attempt to obtain Dumas's support for a post in Paris. This is reinforced by a second letter written in September while Wurtz was travelling in England[59], in which he reminded Dumas of a "promised mission"[60]. In fact, this same year (1844) he went to Paris and entered Balard's laboratory at the Sorbonne, but he only stayed for a very short period. He soon moved to Dumas's private laboratory in the Rue Cuvier, where he carried out research and met Cahours, Melsens, Lewy, Le Blanc and Bouis. In 1845, Wurtz was appointed Dumas's préparateur at the Faculty of Medicine and Eugène Caventou[61] was chosen by Dumas to be Wurtz's first élève. In addition, under Dumas's patronage he was also appointed chef de travaux chimiques at the Ecole Centrale des Arts et Manufactures, and he held this post until 1850. He also made an attempt to be appointed conservateur des collections de chimie at the Ecole Polytechnique, but he failed[62].

In this period (1844-1845), Wurtz undertook the translation of Gerhardt's first book, Précis de chimie organique (1844-1845) into German. In this book Gerhardt introduced the concept of homology[63] and presented a new system of nomenclature and classification of chemical compounds. These were organised in "families" and their respective names had to express the "genus" and "species"[64], according to the process through which they had been generated. The current German names, however, were not able to meet these requirements, but apparently Wurtz's endeavour overcame these difficulties, since Gerhardt described his work as excellent[65]. Although they had been contemporaries at the Gymnasium, Wurtz was actually one year younger than Gerhardt, their personal relations seemed to have been rather superficial, at least during Wurtz's youth and early career[66]. The translation of the book, nonetheless, was probably due to Wurtz's initiative[67], which reveals how much he had been sympathetic to Gerhardt's challenging views since the very early stages of his career. Yet their full adoption by Wurtz was only to occur in 1851. Such a translation, however, and the fundamental problems it involved, might have provided Wurtz with a deep understanding of the insights put forward by his fellow Alsatian. This profound awareness may explain, therefore the way in which he was to establish the scientific programme of his research group.

During the next few years it is probable that Wurtz developed another important relationship this time with Williamson[68], himself a former pupil of Liebig (1844). The English chemist had established a private laboratory, in Paris (Rue Bourgeois), between 1846 and 1849. His contacts with Dumas, but especially with Laurent and Gerhardt led him to chemical investigations of major importance for the development of Gerhardt's type theory. Wurtz and his école were to explore and extend it and consequently he was to have as élèves former students or assistants of Williamson, as it will be seen in the following sections.

In 1847 Wurtz was appointed agrégé de chimie at the Faculty of Medicine[69] after a competitive examination and two years later another step forward was to occur through his nomination as Dumas's suppléant at this same Faculty. Holding this post until 1853[70], he was given a small and dark laboratory in the attic of the Musée Dupuytren[71] and as a neighbour he had Favre, who was then beginning his experiments on thermochemistry.

In an attempt to achieve better conditions to carry out his experiments, Wurtz joined Dollfus and Verdeil, recently returned from Liebig's laboratory in Giessen, to open a private laboratory in the Rue Garancière. They intended both to perform private investigations and also to receive some élèves for research training. For this enterprise, Dollfus, an Alsatian belonging to a traditional family of industrialists[72], contributed money, Verdeil[73] his entrepreneurial abilities, and Wurtz undertook the scientific directorship. The origin of Wurtz's later école may be traced back to this laboratory. Among the élèves who work under his and Verdeil's supervision were William Marcet [74], who engaged in biological chemistry, Risler[75], who devoted himself to agricultural chemistry, Scheurer-Kestner[76], who was a member of an Alsatian family of industrialists and engaged in applied chemistry, and finally Perrot, who later became Wurtz's préparateur at the Faculty of Medicine. This private initiative, nevertheless, was not successful since in 1853 the building where the laboratory had been established was sold to the publishers Plon. During this period Wurtz joined the Société Philomatique[77], often called the ante-chamber of the Académie des Sciences. As a member of this society he established several contacts with savants aspiring to a position in the Académie.

In 1850 Foucault, one of his colleagues in the Société Philomatique published an article in the Journal des débats politiques et littéraires[78] in which he reported on the recent developments of organic chemistry. Praising Wurtz's contributions[79], he singled out his research paper on amines presented to the Académie des Sciences and recommended for publication in the Mémoires des savants étrangers. In this same article the author of the famous pendulum addressed criticisms to the Moniteur, because Wurtz had not been included in the list of those awarded the Légion d'Honneur[80], and also to Dumas, whom he accused of negligence towards his former élève. Apparently Foucault's article had been published without Wurtz's knowledge and, the latter, realising the potential danger of losing Dumas's patronage, wrote to him showing signs of deep embarrassment[81]. Yet this incident seems not to have affected their relationship and Wurtz was, in fact, made Chevalier of the Légion d'Honneur later in this same year, and continued to have Dumas's support.

When the Institut Agronomique of Versailles was founded in 1850, Wurtz was appointed professor of chemistry, having as chef de travaux chimiques his associate Verdeil and as préparateur Riche[82]. As already mentioned, for political reasons this institution was closed in 1852[83], the year Wurtz married a childhood friend of some fortune. It was in 1852 that he undertook the regular translation of articles of foreign chemists for the Annales de Chimie[84], a well-established journal of the greatest prestige in the European scene. This task was of major importance because it enabled him to be aware of the research carried out in several European centres as well as providing him with a network of international contacts. These contacts, together with those he had made in Giessen, England and at Dumas's laboratory, very much contributed to build up an international dimension. Internationalism was, thus, to become a conspicuous feature of Wurtz's philosophy and also of his école, in a way not comparable with his Parisian colleagues and their respective groups.

The year of 1853 was to bring Wurtz some reparation for the loss of his post at the Institut Agronomique. He was promoted to professor of chemistry at the Faculty of Medicine, as the result of both Dumas's resignation from his professorship owing to his political engagements, and the death of Orfila[85]. According to several testimonies, the lectures were crowded with students and Wurtz's teaching was characterised by great enthusiasm[86] and exuberant performances[87]. Unlike many of his contemporaries in his teaching he valued both theory and practice, since he considered them intrinsically related. Also, unlike his most outstanding colleagues, he taught openly the atomic theory in his lectures and textbooks. But above all, as Friedel mentioned:

> It was not simply an audience he found at the Faculty of Medicine, but all that was required to create a true école of chemistry.[88]

2.2- Wurtz's early research

In the process leading to the establishment of an école the research carried out by the future chef d'école was obviously of major importance in order to bring recognition from the scientific community. First of all, this was one of the requirements to be given a senior post, a laboratory and attract potential élèves. In addition, the analysis of these early investigations, in Wurtz's case, provide indications about the process which led him to the definition of the theoretical foundations of the research programme, which was to be explored by his école.

From the theoretical point of view, when Wurtz began his research in Giessen (1842), organic chemistry was already beset by a number of different and often conflicting views regarding the representation of organic compounds. On the one hand Lavoisier's dualism later extended by Berzelius's electrochemical approach, was increasingly contested by organic chemists. On the other hand, Dumas's substitution theory and Laurent's more structural approach (1836) to organic compounds were controversial. Finally, Liebig's theory of radicals was far from being generally accepted and was especially denied by Laurent and by Gerhardt, who pointed out that radicals had never been isolated. At this stage Gerhardt only accepted formulae written according to unitary theory. This theory claimed that chemical compounds should be envisaged as a whole whose parts could be exchanged by substitution, producing series of related compounds. But unlike his friend Laurent[89], he advocated that the arrangement of atoms was not accessible either to reasoning or experiments. Moreover, he radically conceived reactions only taking place by substitution, which was just the opposite of the dualistic theory, which claimed that reactions can only take place through addition. Wurtz entered the chemical scene in this context, in which the coexisting theories were highly controversial.

Although often considered as the heir of Gerhardt, who died in 1856, leaving his programme only partially explored, Wurtz adopted a critical perspective to the ideas of the man who inspired him. Yet, if it is true that the theoretical basis of his research and that of his école came close to Gerhardt's views, these were not followed strictly, and contributions from other chemists were also taken into account . The analysis of the research carried out during the first ten years of Wurtz's career as a chemist already provide evidence of the way in which he was to accommodate and integrate different views in his own framework.

From the investigations he carried out between 1842-1853, which focused on three major lines - phosphorus acids (1842-1845), the derivatives of cyanogen (1846-1853), and butyl alcohol (1850) - he was to derive several conclusions with theoretical impact. His first work on phosphorus acids began in Giessen and continued at Dumas's laboratory[90]. He aimed at finding out the composition of hypophosphorous acid. Wurtz's initial goal was to decide, through the analysis of several derived salts, between the two formulae respectively attributed by Dulong (P^2O^3) and by Rose (PO). But from his experiments he was led to assume, unlike his predecessors, that this acid contains what he called the elements of water, HO. Repeating his experiments Wurtz extended his assumption respectively to phosphoric and phosphorous acids, concluding that this "water" HO[91] was not, however, combined with these phosphorus acids as such. He then claimed that these three acids have the same amount of hydrogen by reference to phosphorus, but their capacity to react with bases increases with their increasing proportion of oxygen. Thus, he concluded that the hydrogen and the oxygen are constitutive of these acids, establishing their formulae as follows[92]:

Hypophosphorous acid	PH^3O^4	
Phosphorous acid	PH^3O^6	(O=8)
Phosphoric acid	PH^3O^8	

This series of experiments had two major implications, which contradicted current ideas. First, he introduced into chemistry the notion that the hydrogen present in an acid does not determine its basicity, and second, that the basicity increases for a given radical to the extent that its constitutive oxygen increases. Although applying substitution theory and Gerhardt's emerging type theory, Wurtz put forward some claims, which were in contradiction with those of his fellow Alsatian, at this stage. Notably, he was applying in these studies Liebig's notion of a radical, and he aimed at reaching an understanding of the internal arrangement of chemical compounds[93], which was beyond the bounds of possibility, according to Gerhardt.

During this period (1842-1846), he also published (1844) a piece of research on copper hydride[94], which led him to an important theoretical conclusion. He studied the action of hydrogen chloride on copper hydride[95] and he observed that it decomposes, giving an amount of hydrogen, which is double of that present in the hydride. He concluded that the hydrogen liberated in this reaction should be represented as H^2 instead of H, as it was currently accepted, since one atom of hydrogen of this molecule comes from the hydride and the other from the acid. Wurtz generalised from this conclusion, claiming that simple bodies such as hydrogen are formed by two atoms of the same species which united. Laurent generalised this interpretation and, taking this example together with those of gaseous chlorine, oxygen etc., he was led to distinguish in 1846 in an article published in the Annales de Chimie[96] the difference between an atom and a molecule. Both Wurtz's claim and Laurent's subsequent distinction, however, were absolutely unacceptable by dualists, to whom it was impossible to conceive the union of two electropositive or two electronegative elements[97].

In 1847, taking up again the line of his investigations of phosphorus acids, he published an article on his discovery of sulphophosphoric and phosphorus oxychloride[98]. Between 1846 and 1853, he engaged in another topic of research, i.e., on the combinations of cyanogen, which was to lead to the discovery of amines. Following Liebig's suggestion that ammonia was the type of all organic bases[99], Wurtz prepared in 1849[100] what he called "methylamide" and "ethylamide" (in fact methylamine and ethylamine, as he was to call them in his second article), by heating the "cyanic ethers" (in fact isocyanic esters) with caustic potash. This discovery, which impressed the chemical community and especially Liebig and Dumas, was to generalise the views of the these two chemists, who advocated the idea that radicals could play in a molecule a similar role to that of simple substances[101]. Also Hofmann (1850) interpreted his discovery of diethylamine and triethylamine, according to Wurtz's views. Accordingly, the ammonia type was established as follows, assuming that the hydrogen of ammonia can be replaced by ethyl groups[102]:

$$Az\begin{cases}H\\H\\H\end{cases}\qquad Az\begin{cases}C^4H^5\\H\\H\end{cases}\qquad Az\begin{cases}C^4H^5\\C^4H^5\\H\end{cases}\qquad Az\begin{cases}C^4H^5\\C^4H^5\\C^4H^5\end{cases}\qquad (Az=N;\ C=6)$$

Ammonia type (Wurtz) (Hofmann) (Hofmann)

These studies provided the necessary evidence for the establishment of the ammonia type and greatly reinforced Gerhardt's developing type theory. Gerhardt himself was to introduce the designation of primary, secondary and tertiary amines, to translate the substitution of one, two, or three atoms of hydrogen by carbon chains. At this stage, Wurtz persisted in his view of the importance of knowing the internal arrangement of atoms in a molecule through the study of reactions[103]. Despite the fact Gerhardt had moved in 1853 to a less radical position, he was still advocating that formulae could only describe reactions[104].

Pursuing this line of investigation, Wurtz concluded in 1853 that the reactions of "cyanic ethers" with acids produced substituted amides. He interpreted (1854) these reactions by regarding amides as derivatives of acids, whereas Gerhardt[105] preferred to refer them to the ammonia type. Finally in 1854 Wurtz changed his focus and carried out experiments which led him to the isolation of "butyl alcohol"[106] (in fact isobutyl alcohol), from potato oil. Yet, the importance attributed to the discovery of a new alcohol was no longer equivalent to the discovery of a new element, as in the days of Cahours, which shows how quickly values were changing within organic chemistry. In addition to an extensive study of isobutyl alcohol derivatives, one of the major results of these investigations was the method of preparing esters from a reaction of an alkyl iodide on an organic silver salt. This method later proved to be particularly fruitful to Wurtz and several of his élèves. Notably, he was to apply it when he discovered glycol in 1856.

2.3.- His career after 1853.

Wurtz's appointment in 1853 as professor of chemistry at the Faculty of Medicine ultimately corresponded to the fulfilment of two pre-requisites for the establishment of his école.: one being the status associated with his post, the other the space to which he was entitled, which he and his élèves were to convert into a research laboratory. Although he was not allocated any budget for research by the administration, he adopted a solution which clearly denotes a different ethos, and in particular a different relation to money[107]. Thus,unlike his colleagues who only had considered the possibility of obtaining funds coming from official channels, Wurtz adopted a position which emerges as stressing his belief in individual initiative, independence from the state and self sufficiency. Thus, he decided to collect a fee from his élèves, which was to pay current expenses of the laboratory, personnel, reagents and apparatus costs. In this way he also preserved his independence as regards topics of research, which were not obliged to follow official policies as in the case of Pasteur and Deville.

In the process of building up his école, the recruitment of Wurtz's élèves was obviously of major importance. Although Friedel's comment[108] may have led us to think that Wurtz recruited his élèves amongst the students of the Faculty of Medicine, with few exceptions this was not to be the case, as it will be seen in Chapter 3. Presumably both the subsidiary role of chemistry in medical training and the high and well defined social status of medical profession in French society were the main reasons. Both Wurtz's Alsatian origin and background, as well as his international contacts and prestige seem to have determined the way in which the élèves were attracted to his école.

Meanwhile Wurtz's investigations led him to the discovery of glycol in 1856. To this discovery he attributed the greatest importance, not because a new compound had been discovered, but because it had been predicted. This obviously reinforced the theoretical framework that he and his élèves were implementing, and opened up new lines of research[109]. Between 1856 and 1858, Wurtz's research and activity gained him some recognition, and he was elected to the Académie de Médecine (1856) and was awarded the Jecker Prize of the Académie des Sciences (1858), which he won jointly with Cahours.

Following Wurtz's establishment as chef d'école in 1853, the foundation of the Société Chimique de France in 1858, was to add to the power and influence of his école [110]. This society, which had begun (1856) as an informal group of young chemists including some of his élèves was soon converted into a formal institution, when the promoters decided to call Wurtz in. As a maître he already possessed enough status to lead the project, and his école was more able to affirm its position in the chemical scene, especially within France. For a long time Wurtz's école was to hold the control of the new-born Société inasmuch that Wurtz undertook the responsibility of organising its publications[111]: the Bulletin devoted to the publication of original research submitted to the Société; the Répertoire de chimie pure, which summarised the research published in France and abroad and finally the Répertoire de chimie appliquée, whose responsibility was that of his friend Barreswil[112]. Wurtz shared these editorial tasks with his élèves and converted these journals into an effective organ of his école. In 1864, these three publications were fused into one, the Bulletin de la Société Chimique de France which had the collaboration of a network of foreign chemists from Lisbon to St. Petersburg, the majority of them having been Wurtz's former élèves.

The Société was to reveal some of the features Wurtz impressed on his école: it had been a product of an independent but collaborative initiative of a group of individuals, it was funded through the payment of a fee by the members, it had an international dimension and a pluralism of views. Notably a greater pluralism of ideas on chemical theory was admitted in the Société than in the école simply because the lines of a research programme were not at stake. In the Société, however, chemists like Berthelot or Deville and their respective élèves were able to express in their articles published in the Bulletin chemical views opposed to those of Wurtz's école and on several occasions they were elected to the posts of president or vice-president.

These posts, more honorific than effectively influential in practical terms, emerged as a diplomatic means framed within a general policy of good neighbourliness. In fact, the Société Chimique was described as "our great chemical family"[113].

Chemical theory was indeed a controversial matter at this time. Internationally chemists were far from reaching consensus over formulae and nomenclature of organic compounds. Particularly they were unable to decide between the atomic weights and equivalents. In 1860 Kekulé, then professor at the University of Ghent, his friend Weltzien of Karlsruhe and Wurtz decided to organise an international meeting in Karlsruhe to discuss these questions in an attempt to reach unity in chemistry. From the French side Berthelot was absent, whereas Dumas assumed a conciliatory role as chairman of the last session, by suggesting different conventions for mineral and organic chemistry, respectively. The meeting did not bring the chemists to a consensus, but a great deal of unanimity was achieved afterwards, through an article distributed by Cannizzaro[114].

As a result of Wurtz's discovery of glycol (1856) and of the subsequent investigations of its derivatives carried out by his élèves, he delivered a lecture in the Société Chimique entitled "Histoire générale des glycols". In this lecture many of the contributions of his élèves were acknowledged, and to a certain extent, it may be considered a contextualised summary of much of the research activity developed by his école. Two years later, in a meeting of the Société des Amis des Sciences[115], Wurtz delivered a posthumous eulogy of Laurent and Gerhardt in which he expressed his scientific indebtedness to these chemists, who had inspired him. In June of this same year, not in Paris but in London during the Universal Exhibition, he proclaimed the unification of chemistry with a manifesto-like article entitled "On oxide of ethylene considered as a link between organic and mineral chemistry"[116]. The idea of unifying chemistry was not a novel one, and had been previously advocated notably by Dumas and Berzelius. But Wurtz was to develop it further than Dumas and in the opposite direction to that of the Swedish chemist, i.e., he defended unification on a common ground, that of atomic theory, which had been developed through organic chemistry.

During 1863 Wurtz participated in a series of lectures delivered at the Société Chimique, and reaffirmed the views on the unification of chemistry he had presented in London, in which the role of atomicity[117] was particularly emphasised in the classification of both mineral and organic compounds. This same year he was promoted to the rank of Officier of the Légion d'Honneur, and in 1864, he was awarded a second Jecker Prize and was elected a member of the Royal Society. Unlike other colleagues, to whom this accolade was to follow several years after their election to the Académie des Sciences[118], in the case of Wurtz this election to the Royal Society preceded by three years his election to Académie des Sciences. This suggests that Wurtz's part in the formulation and development of chemical theory was played on the European chemical stage rather than simply in his native country. Indeed, from the point of view of chemical theory he found a greater echo in and was more in tune with British and German centres than with French official science.

Also in 1863 he published his book, Traité élémentaire de chimie médicale dedicated to the students of the Faculty of Medicine, in which he dealt with the application of what he called "modern chemistry", to physiology, pathology, pharmacy and hygiene. In 1864 he published Leçons de philosophie chimique, in which he presented in a systematic form the underlying principles that had presided his personal research and that of his école. The next year the Académie des Sciences awarded him the Prize Napoleon III amounting to 20,000fr..In addition, Wurtz's power within the institutional setting of both his professorship and of his research laboratory was enhanced this same year, through his election as Dean of the Faculty of Medicine, succeeding Rayer and Tardieu. The deanship of his predecessors had been marked by intense political struggle, since the Faculty of Medicine had been a stage for political confrontation and manifestations of hostility towards the regime of Napoleon III.

According to several testimonies[119], Wurtz's deanship was firm, balanced, independent and highly regarded by students and staff, which may explain why Wurtz kept the post for so long[120] with a major internal support. While Dean he introduced several internal reforms with implications at three levels: pedagogical, administrative and as regards the internal modus vivendi. Thus, with the support of his colleagues, he launched a programme for the implementation of laboratory training for students, covering the majority of the medical courses, and eventually he obtained higher budgets from the central administration[121]. This programme culminated in the rebuilding of the Faculty of Medicine in 1877. His visits to foreign laboratories, especially in the German States, Austria and Hungary (1868-1878) at the request of the Minister of Education[122], embracing laboratories of chemistry, physics, physiology and other medical subjects, were intended to provide information for the construction of laboratories in the Faculties of Medicine of Lyon, Bordeaux, Lille and Nancy. These reports were published[123] and the detailed accounts given provide a picture about the way in which the different laboratories were conceived at this period[124].

But Wurtz's style as a Dean also had implications for the way in which disciplinary problems were dealt with, within the Faculty[125]. Especially regarding students, these questions became acute particularly in moments of political instability, in which he advocated with eventual success, that these matters should not involve either the police or the courts as was usual and consistent with the centralised forms of control used by the French administration, especially after Napoleon I. Instead they should be solved inside the institution even if sanctions were found to be necessary. As regards disciplinary questions involving staff, Wurtz's defence of Robin[126] and of his former élève Naquet (a renowned socialist at the time) earned the respect of many of Wurtz's élèves. One political faction had requested both Robin's and Naquet's dismissal, with the accusation that they were inculcating their students with materialistic ideas. Despite his different political views, Wurtz undertook their defence, invoking individual freedom of opinion as a right[127].

Another innovation he introduced in the Faculty of Medicine was the admission of the first group of women in 1867-1868, despite the opposition of the majority of his colleagues[128]. As the law omitted the question, Wurtz took the opportunity and at least in one case he claimed the direct intervention of the Minister of Education Duruy to decide on behalf of women students[129]. Wurtz's initiative created a precedent and gradually women were admitted in the faculties of sciences, law and humanities[130]. In this pioneering role he was joined by his élève Gautier, who at the time was member of staff at the Faculty of Medicine. The same policy of access of women to science was also to be implemented in publication, especially in the Bulletin of the Société Chimique, in which the most striking contingent was that of female Russian correspondents, many of them trained in the Faculty for women created in St. Petersburg in whose foundation Butlerov, himself a former élève of Wurtz[131], had been engaged. Thus, Julia Lermontova, a former student of Butlerov, was to become in 1878 responsible for the section "Correspondence Russe" of the Bulletin, in which she reported the work of Russian chemists, including her own.

In 1867 Wurtz was elected to the chemistry section of the Académie des Sciences where he replaced Pelouze and in his election he had both Dumas's support and that of the majority of the Academicians, and in this way he acquired an influential share in the scientific establishment. At his election in a hand written note sheet of the meeting, among other aspects Dumas pointed out the reasons for Wurtz's election, in the chemistry section:

> Unanimous section.
> The Académie balanced - Sciences of organisation, Chemistry.
> Preference for chemistry due to his great services-ammonia compounds, urea, glycols, ethylene oxide.
> Distinguished family.
> Disinterested, creative, skilled and loved professor.
> Incomparable and secure experimenter.[132]

This same year Wurtz published his book Leçons élémentaires de chimie organique for pupils of the lycées, which had five editions up to 1884, despite the official hostilities to its underlying atomic theory. The next year he was to start publishing his Dictionnaire de chimie pure et appliquée (1869-1878), in which he had the collaboration of many of his élèves[133]. He was also temporarily appointed as suppléant for Pasteur at the Sorbonne[134] where he was to request the establishment of a chair of organic chemistry in 1871.

With the outbreak of the Franco-Prussian war and the annexation of Alsace, Wurtz interrupted his normal tasks and became engaged in humanitarian activities which covered several aspects, as the ambulance service[135] in which he collaborated as a doctor. Also the Société de Protection des Alsaciens-Lorrains in whose foundation he participated together with other Alsatians, helped to settle not only those who escaped from the Prussians and sought refuge in Paris, but also the refugees who settled all over France and in Algeria[136]. The war obviously interfered with the activities of his école and during the siege some of his foreign élèves tried to escape the conflict. Wurtz's good relations abroad helped them and notably the American Crafts and the Portuguese Silva came to Williamson's laboratory in London[137].

Appointments to posts in the academic hierarchy were in France partly dependent on the political situation. After the war and with the fall of the Second Empire, Wurtz decided to resign from his deanship at the Faculty of Medicine, since he had been appointed by the Imperial administration. The Faculty, however, asked him to stay and to continue his programme of internal reforms[138]. This may be explained by his politically uncompromising position with the Second Empire, and his independence regarding the practices of central administration in running the affairs of the Faculty, which brought him popularity among its population. Moreover, he had been not confined by his personal interest in chemistry and the reforms he had introduced involved the Faculty as a whole and the interests of the medical community. Also the international prestige of his école by the late 1860s added to the reputation of the institution, which was outside the aura of the grandes écoles. The confirmation of his deanship marked, in addition, a period in which Wurtz was gradually to be chosen for further honorific positions, denoting his integration in the establishment, which added to his power. Thus, as a further confirmation of his status within the medical community he was elected President of the Académie de Médecine in 1871 despite his commitment to chemical research.

But the war had additional implications by stimulating his personal involvement and that of his école in other activities with impact in a wider context. Notably, the foundation of the Ecole Alsacienne de Paris (1871), and the Association Française pour l'Avancement des Sciences (1872), which will be analysed in due course[139] as an activity of Wurtz's école .

In 1875 Wurtz requested and eventually obtained the creation of a chair of organic chemistry at the Sorbonne. He aimed at moving his école to this institution and leaving definitely the Faculty of Medicine, because as a Faculty of Science he thought the Sorbonne to be more appropriate for chemical research[140]. With this new post he resigned from his deanship at the Faculty of Medicine, but was unanimously nominated its Doyen Honoraire[141]. At the Sorbonne, nevertheless, he did not possess any laboratory facilities, not even for teaching, but he collaborated in the plans for a new research laboratory to be built later in the 1880s. However, Wurtz died before its completion. Meanwhile as Professor of chemistry at the Sorbonne he attempted the full adoption of the atomic theory in the several chemistry courses[142], but with difficulty, mainly because of the opposition from Deville and his école, who held the majority of the teaching posts related to chemistry.

In 1875 Wurtz initiated his civic commitments by becoming the Mayor of the 7 ^{e} Arrondissement in Paris, but soon he resigned due to his multiple engagements. He was replaced by his fellow Alsatian Charles Risler, who had helped him in those functions.

The controversy over the atomic theory was to erupt in 1877 in the Académie des Sciences, which opposed Wurtz to Deville and Berthelot[143], but it was to leave the situation as before. In this same year, with Wurtz's support, his élèves Salet and Henninger decided to launch the publication of the Agenda du Chimiste, based on the private handbook of his laboratory[144]. In 1878 Wurtz repeated his election of 1874 as President of the Société Chimique and was invited by the Royal Society to deliver the Faraday Lecture[145], and while in England he was to receive hospitality from Williamson, Warren de la Rue, Siemens and Spottiswood. His election for the Comité Consultatif d'Hygiène Publique and his membership in the Council of the Légion d'Honneur was to occur in 1879 as well as the publication of his book La théorie atomique, in which he included a physical perspective of matter based on the studies of Lord Kelvin, Clerk Maxwell, Clausius, Loschmit and Herapath.

In 1880, Wurtz became vice-President of the Académie des Sciences, and the next year he was to be awarded the Copley Medal of the Royal Society. He also became Grand-Officier of the Légion d'Honneur and was nominated to the Senate by the centre left wing of the Republican Party, which marks his formal involvement in politics.

With all these accolades and also his formal political involvement, Wurtz fulfilled many of the conditions required by his ambition to become Permanent Secretary of the Académie des Sciences to succeed Dumas. According to Friedel, he had enough support from his colleagues[146] and he envisaged this post as the "coronation" of his whole career. He died, however, on 12 May 1884, the same year he was asked to deliver the eulogy of his maître Dumas. Ironically Dumas's place in the Académie was to be occupied later by Wurtz's rival Berthelot, since Deville had died in 1881 and Pasteur due to health reasons, only assumed it for two years (1887-1889) and resigned.

3.- His Ideas: Wurtz's cosmology in the "New Atlantis". From the test tube to the Universe.

Wurtz was undoubtedly more a man of action than a man of words, in the sense that he influenced other people rather by his practices than by his ideological writings. Indeed, unlike Berthelot, who devoted much of his time to making speeches and writing articles and books on the philosophical, social and moral implications of science in accordance with his positivistic principles, or Pasteur, who wrote several articles with strong ideological implications, criticising the state of French science and prescribing what he considered the appropriate measures, Wurtz produced comparatively little prose of this kind.

In this section the main concern will be to present Wurtz's personal ideology presented in public language as it was formulated in his own maturity, i.e., after more than 20 years as an established *savant* and as a *chef d'école* . For this purpose the focus of attention will be his only public paper with clear ideological motivations that he delivered in a meeting of the Association Française pour l'Avancement des Sciences (AFAS), which took place in Lille in 1874. Wurtz was at this time president of this organisation, which had been created after the French defeat in the Franco-Prussian conflict. The analysis of the content of this speech entitled "La théorie des atomes dans la conception générale du monde"[147], is particularly significant, since it located his personal ideology, chemical theories and scientific practice in a general and wholistic conception of the Universe. This global approach which had little in common with the views of his French contemporaries, denotes the German influence on Wurtz, an influence that the specific post-war circumstances as well as his loyalty to France did not allow him to express clearly.

As a man of his time Wurtz used the historical approach in this document to legitimate both his scientific programme and his vision of the world including his own internationalist practices. Accordingly, he adopted the perspective of a history of science in which ideas were developed in a continuum[148] and, in order to serve better his own claims, examples from the past and present were selected. In order to trace the roots of his personal ideas he was to choose, due to the public circumstances, Francis Bacon, a sufficiently neutral philosopher whose empiricism could please the strong positivistic trend among French savants but, at the same time, he was to present an unusual reading of his British source of inspiration. Especially, and in order to legitimate his internationalism and the strong cosmopolitan dimension of his école, he considered a real New Atlantis was about to be built:

> Two centuries ago Bacon's conception could be envisaged as a generous utopia. Today it became a reality. This magnificent programme he had designed is our programme not in the strict sense of the word, because I extended it to all those that in our modern times are engaged in the search of the truth, to all artisans of science, either humble or great, obscure or famous. Indeed they form without distinction of nationality, this vast association of which Francis Bacon dreamt.[149]

Wurtz was advocating in his speech to the AFAS the model underlying his école, whose activity was now well known and in which a mixture of élèves of different nationalities was a part of a network of private and scientific communication with foreign centres. In fact, his école had been framed rather in the ideal of a community sharing common interests and possibilities than in a paternalistic model of organisation. As a corollary, Wurtz was led to claim the neutrality of science, conferring on it a super-national dimension as an indispensable requirement for his real New Atlantis:

> Yes science is today a neutral field, a common goal located in a serene region, superior to the political arena and inaccessible, as I would like to say, to the struggles of peoples and parties. In a word it is a property of mankind.[150]

By contrast, in the majority of his colleagues' discourse the main concern was the scientific superiority of France[151] and at this point German savants had been excluded from scientific meetings with the accusation of involvement in the affairs of war. But what did Wurtz meant by science in that "century of science", to use his own words? And what should be its methods?

Wurtz took up again the line of Bacon's philosophy for several purposes: to define scientific method, to justify his adoption of atomic theory, to advocate the applications of science and also to establish his views on science and religion. His reading of Bacon, however, did not follow the most widespread interpretations of his philosophy[152]. Thus, as regards science and particularly its method Wurtz did not restrict Bacon's programme to the current interpretation which emphasised a strict empiricism and induction. He took it rather in its "theoretical model building"[153] facet. In addition, he linked to Bacon several Romantic trends in which knowledge was seen in a wholistic form in which all its branches both scientific and non-scientific, including history, languages, ethics and art were equally valued[154]. Knowledge was thus seen as the discovery of hidden analogies[155] and of the intimate nature of phenomena. And while for literature and art what was involved was the expression of aesthetic concepts both in Nature and in the spirit, for science, which he conceived as a special form of the "struggle against the unknown" the task was to reveal the "deeply hidden truth"[156] in Nature. He then emphasised the importance of method, arguing that the development of experimental sciences such as physics, chemistry, and physiology had been possible by "the progress of methods , i.e., by accurate observations, by more sophisticated experiments by more rigorous and severe deductions"[157].

It was from his position of chemist and from his concept of matter, which he considered the central question in chemistry, that he was to exemplify the scientific progress that he considered that so far had been achieved. Departing from Lavoisier, to whom he attributed the origin of modern chemistry, he discussed his dualistic hypothesis on the composition of salts and its further extension to all chemistry by the electrochemical dualism of Berzelius. He was to argue , nevertheless that the hypothesis of atoms had provided chemistry with a steady basis after Dalton. According to Wurtz, Daltonian atomism was less a speculation than that of the ancient philosophers or of the Cartesian school but rather "the theoretical representation of well-known facts"[158], such as the fixed proportions and multiple combinations. Wurtz was to take a phenomenological approach and with his representation of <u>savant</u> as an artisan or a craftsman, he was to ascribe to atoms not the status of a given fact, but that of an artifact, i.e., a representation of empirical data.

For some time the description of organic compounds had raised fundamental questions. They were formed by a limited number of elements and, to account for the differences among the several substances, dualism had been proved inadequate. Wurtz was thus to consider that the atomic theory and the consideration of inner structures was the only possible way for a description:

> It is not by their general composition that organic compounds differ, but by the number and arrangement of atoms. Through different groupings and arrangements these atoms produce an enormous variety of compounds, which are true chemical species.[159]

The assessment of the composition together with that of these inner structures[160] was thus for him the object of chemistry, i. e., its contribution for what Wurtz called the "eternal question"of constitution of matter. He then mentioned Dumas's substitution theory, Laurent's ideas on the arrangement of atoms and especially Gerhardt's type theory as fundamental tools for a unified classification of both mineral and organic compounds, for their prediction and as an instrument for discovery. Furthermore, as atomic theory implied a system of formulation, he refused that these formulae could be qualified as an "ingenious intellectual exercise"[161], since they had been established on an empirical basis, i.e., they had been derived from the establishment of analogies and relations following the assessment of the reactional behaviour of the various compounds. Unlike his colleagues Berthelot and Deville, Wurtz attributed the greatest important role to the building up of theories and to predictability, without dismissing intuition[162].

In this speech the choice of Bacon's ideas as a paradigm was also to allow Wurtz to justify his position towards the application of science. In his representation of science, he was not to regard application as the opposite of pure science, but for him application was itself contained in the theoretical principles of the atomic theory, and it could be, in addition, a stimulus for science. Accordingly, the chemical compounds with industrial application were themselves, predictable as he exemplified with the derivation of alizarine from rosaniline:

> Here it is a discovery, which came out from the most abstract science, confirming preconceived ideas about the relations of composition and of atomic structures between anthracene, alizarine and intermediate terms.[163]

As a consequence, Wurtz put forward a chemical programme, which reaffirmed his own, whose goals were:

> To discover, analyse, study, classify, reproduce artificially the greatest variety of bodies, to study their intimate structure and indicate useful applications.[164]

In order to put in practice such a programme he criticised strict empiricism arguing that experiments had to be guided by theory and discoveries predicted:

> In chemistry empiricism was overtaken...the detractors of theory, who do not know how to predict, they harvest where they did not sow.[165]

Wurtz did not restrict his programme to chemistry, but emphasised its overlaps particularly with physics and astronomy through the atomic theory, i e., at a microscopic and non directly observable level. Thus, by invoking data from the spectroscopic studies of Frauhenhofer and Kirchhoff as well as Lockyer's and Jenssen's interpretations of solar protuberances, he presented the sun[166] as a star composed of the same terrestrial elements in a dynamic process similar to that of chemical reactions. But this analogy, between earth chemistry and the chemistry of the sun, embraced the whole universe which he conceived as encapsulating a plurality and diversity of worlds in an infinite space. The idea of unity of matter together with search for analogies in nature were themselves arguments associated with Naturphilosophie, and led Wurtz to claim the Romantic principle of unity of knowledge despite the different objects of the different sciences. This interpretation did not imply any form of hierarchical classification of sciences as claimed by positivists and, therefore, for Wurtz sciences such as chemistry, physics and astronomy were different approaches by sharing the same common "fabric", i.e., matter in a dynamic state[167].

The analogical argument based on the identity of matter when applied to both the infinitely small and the infinitely large led Wurtz to affirm the existence of an intrinsic order in Nature and to the admission of a teleological principle of divine nature. He was to express his belief in a separation between science and theology, which had avoided him many of the inner conflicts that several of his contemporaries experienced. Leaving the "primary causes" to God these were converted in a matter of faith:

> It is in vain that science will claim to be able to reveal to the spirit the structure of world and the order of phenomena. The spirit wants to go further in its instinctive conviction that things do not have themselves their raison d'être, their support and their origin. Thus the human spirit is led to subordinate them to a primary cause, unique, universal, i.e. God.[168]

NOTES TO CHAPTER 2.

1- Of Pasteur was said:

> As the result of an excessive work he (Pasteur) was attacked by paralysis

See GERNEZ, D. "Notice sur la vie et les travaux de Henri Sainte-Claire Deville", Ann.Sci. Ec. Norm Sup., 2 (1894), S1-S70 (S68). See this same account on Deville's life in which he is presented similarly. Also Berthelot represented himself as having fragile health due to overwhelming work, which he manifested often in his correspondence with Dumas. For instance, on 22 Juin 1875 he sent him a memoir and, despite having in front of him many years of career, he mentioned in the enclosed letter :

> L'état présent de ma santé ne m'a permis de la rédiger qu'avec peine...Le temps d'un repos prolongé pour moi est venu, après tant d'années de travail continuel.

. Paris, Archives de l'Académie des Sciences, Dossier Berthelot.

2- As Duclaux mentioned:

> Le maître ne savait pas rire.

DUCLAUX, E., Pasteur, l'histoire d'un esprit, (Paris, 1896), p.137.

3 See, for instance Charléty:

> La vie de Adolphe Wurtz apparait comme celle d'un homme heureux...Wurtz sut allier à des dons extraordinaires je ne sais quelle allégresse de l'âme, quelle joie dans l'action, quelle trempe de caractère que rien ne résista...Wurtz connut à la fois la joie d'être compris, d'être admiré et d'être aimé.

In TIFFENEAU; HANRIOT; HALLER et al., "Le centenaire de deux grands chimistes à Strasbourg, les alsaciens Charles Gerhardt et Adolphe Wurtz", Rev. Sci., 20 (1921), 573-602 (596).

4- In this period this type of connection was usually a part of the eulogies, especially when the character had some unusual feature. See, for instance the cases of Deville whose vivacious character was attributed by Berthelot to his Creole origin. BERTHELOT, M., Science et philosophie, (Paris, 1886), p.237, or Gerhardt, who, because of his dark hair and challenging tone towards the establishment, was rather seen as an inhabitant of the Italian region of Calabria. See GRIMAUX, C.; GERHARDT, C., Charles Gerhardt, sa vie, son œuvre, sa correspondence, (Paris, 1900),p.13.

5- Berthelot, op.cit. (4), p.248.

6- GREGOR, H., "M. Adolphe Wurtz", Feuilleton Scientifique (15 May 1884).

7- See, for instance, "Adolphe Wurtz and his chemical work", Nature, (19 June 1884), 170-172 (171).

8- Gregor, op.cit. (6).

9- Ibid.

10- GAUTIER, A., "Ch.-Adolphe Wurtz, sa vie, son œuvre, sa personalité, Rev. Sci., 55 (1917), 769-781 (775).

11- JACQUES, J., Berthelot.Autopsie d'un mythe, (Paris,1987), p.178.

12- See Chapt. 4, p. .

13- Haller, op.cit. (3), 588.

Also according to Prof. Wieger of Strasbourg:

> Tout Strasbourg connaissait le vif et alerte Wurtz avec sa tête de Gœthe ornée de boucles...Il passait pour un excellent chanteur et possédait un véritable talent

dramatique. Je l'ai vu tenir avec un grand succès le rôle de Reinhold dans Pfingsmontag et ce rôle ne fut jamais mieux tenu.

Quoted from Tiffeneau et al. op.cit. (3), 588.

14- See for instance Gautier, op.cit.(10), 776; Gregor op.cit.(6).

15- FRIEDEL, C., "Notice sur la vie et les travaux de Charles-Adolphe Wurtz", Bull. Soc. Chim. Fr., 43 (1885), 1-80 (30).

16- See Chapt.3 and Appendix 1 and Chapt.4, section 1.

17- HANRIOT, M., "Notice sur la vie et les travaux de Charles Friedel", Bull. Soc. Chim. Fr., 24 (1900), 1-16 (3).

18- This is aligned with the German Romantic tradition in which the unknown was itself part of knowledge. Accordingly, knowledge was not only made of certainty but of the uncertain and of the debatable, which should be expressed, even in the lecture theatre. See the contrast between Helmholtz in Introduction Wurtz as regards teaching the "uncertainties" of atomic theory, and Berthelot who argued that the atomic theory due to its "uncertainties" was confusing for students. See WURTZ, "Sur la notation atomique", C.R., 84 (1877), 1349-1355 (1350) and BERTHELOT, M., "Réponse à M. Wurtz, relative à la loi de Avogadro et à la théorie atomique", C.R., 84 (1877), 1189-1195 (1192).

19- The new theories were the dissociation theory and the thermochemical work of Berthelot.

20- Gautier op.cit. (10), 777.

21 See Chapt.4. p.

22 Gregor, op.cit. (6).

23- Gautier, op.cit. (10), 777.

24- Friedel, op.cit. (15), 23.

25- Conservative Republican generally meant in this period often to be anti-clerical, but without being anti-religion. Usually it also meant to be against the protectionism of state, advocating free individual initiative. In addition, it often implied a criticism of strong nationalism, which was thought to lead to the isolation of France.

26- Friedel op.cit. (15), 24.

27- Ibid.

28 Ibid.

29 Ibid., 25.

30- See note 1.

31- Although, Berthelot's death had been presented at the time in very moving terms, emphasising his affection for his wife, it seems to have been due to suicide. Jacques, op.cit. (11), 52 and 266.

32- Friedel mentioned that Wurtz's death was due to a bladder disease. Friedel op.cit.(15), 32.

33- FIGUIER,L., "Adolphe Wurtz", L'Ann. Sci. Ind., 28 (1884), 539-544 (543).

34- Wurtz is often mentioned as being born at Wolfisheim, the village in which his parents resided. In 1858, however, the Académie des Sciences took the initiative of enquiring from the local government of Strasbourg on this matter. The Mayor of this city, in a letter dated 28 May 1958, testified through a copy of Wurtz's birth certificate that, in fact, he had been born in Strasbourg. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

35- He was admitted on 7 July 1826. Friedel, op.cit. (15), 4.

36- Jean Sturm (1507-1589) was a German Lutheran reformer and diplomat, who advocated and practiced the propagation of knowledge through teaching and publication. He founded the Gymnasium of Strasbourg in 1538.

37- LEUILLIOT, P. L'Alsace au début du XIX^e siècle: essais d'histoire politique, économique et religieuse, 1815-1830, (Paris, 1959-1960), vol. 3, p.186-191.

38- LEUILLIOT, .P., "Le protestantisme alsacien", Annales, 5 (1950), 314-333 (322).

39- WILLIAMSON, A., Wurtz's obituary, Proc. Roy. Soc., 38 (1885), 22-34 (23).

40- Adolphe Kreiss was a Protestant pastor and Théodore Kreiss professor of Greek in the Gymnasium and later at the Faculty of Theology of Strasbourg. Théodore is said to have become a second father for Wurtz, his brother and sister, when Jean-Jacques Wurtz died. Friedel, op.cit. (15), 3-4.

41- Friedel, op.cit. (15), 5.

42- See Chapt.4, section 2.1.

43 Alsace was traditionally a region of considerable industrial development. Particularly, as regards the mining, dyestuffs, textile and mechanical industries. Wurtz used to visit these kinds of factories in Rothau, during the summer holidays. Some of them in this region were later acquired by Steinheil, one of his relatives.

44- Emile Kopp, whose father was also a Protestant pastor, was Wurtz's schoolmate at the Gymnasium.

45- These struggles involved Cailliot (Wurtz's Professor of chemistry, a Catholic), T.Lauth (related to Wurtz's élève Charles Lauth, a Protestant), and Duvernoy (related to Friedel, another Protestant).

46- Adolph Strecker (1822-1871), had been in Giessen between 1840-1842, becoming Liebig's assistant. He made important contributions to the study of amino-acids and uric acid derivatives. See FRUTON, J. "The Liebig research group - a reappraisal". Proc. Am. Phil.Soc., 132 (1988), 1-66 (56).

47- Hermann Kopp (1817-1892) attended Liebig's laboratory in 1839. Professor of chemistry in Heidelberg (1863-1890), his work was mainly devoted to the study of physical properties of chemical substances. He is also known for his studies in the history of chemistry (1843-1847). Ibid., 53.

48- Even during the Second Empire, by which time Alsace was more culturally integrated into France, Leuilliot writes:

> Il n'y a pas de classes proprement dites, mais des hommes de telles réligions, de telles sectes et de telles professions.

LEUILLIOT, P. "Bourgeois et bourgeoisies", Annales, 11 (1956), 87-101(94).

49 Leuilliot, op.cit (37),p.157.

50- Ibid. p.160.

51- Leuilliot, op.cit. (38), 331.

52-See Leuilliot, op.cit (37), fn.

53- "Par la liberté des cultes, ils semblent entendre la liberté de n'en avoir aucun". See fn. op cit. (38), 331.

54- See Chapt. 3 and Appendix I.

55-See Chapt. 5, section 2.2.

56- Leuilliot, op.cit. (48), 98.

57- Notably the case of the Zuber family is mentioned as one of those who championed these ideals through publications, but others can be mentioned such as the Dollfus family, and especially Charles Dollfus. Members of both families were to sponsor the foundation of the Ecole Alsacienne de Paris. Ibid., 98-99. See Chapt.5.

58- Letter dated 14 March 1844 (Strasbourg). Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

59- Unlike in the previous letters, in which he addressed Dumas as Monsieur, he now addressed him as Maître. This was written from London on 24 September 1844. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

60- This may have been an appointment. The letter reads:

> Vous m'avez fait espèrer que vous vous occuperiez de moi pendant mon absence. Permettez-moi de vous rappeler cette promesse, dont l'accomplissement me ferait un plaisir infini. Je sais bien qu'il ne dépend pas de vous seul de me faire donner la mission dont vous m'avez parlé avant mon départ..." Ibid.

61- His father, who had isolated quinine was a friend of Dumas and admired Wurtz's early work, which may explain Dumas's choice. J.B. Caventou used to invite Wurtz to his house and through his influence supported him on several occasions. Williamson, op.cit. (39), 25 and Friedel, op.cit. (15), 9.

62- The administration chose E. de Saint-Evre, a former élève of Dumas.

63- Gerhardt used the term homologous series, to describe series of related compounds, the successive members of which differed by CH_2. These compounds would undergo changes according to similar equations, allowing prediction of reactions. It was only necessary to know the reactions of one to predict those of the others. According to Gerhardt, homologous compounds had similar properties.

64- As Gerhardt explained in his letter to Wurtz dated 9 January 1844:

> Il faut nécessairement que chaque nom exprime le genre et l'espèce du corps; les noms systématiques allemands ne remplissent pas ces conditions, et cependant cela me paraît fort important car c'est là précisément ce que ma nomenclature offre de nouveau

Paris, Archives d l'Académie des Sciences, Don Tiffeneau, Dossier Gerhardt.

65- Ibid.

66 See Grimaux; Gerhardt , op.cit. (4), p.440.
Also the way in which Gerhardt addressed Wurtz in their correspondence gives a clear indication: in the 1844s as Monsieur, in the 1855s it moved from collègue to ami. There are, however, some signs that Gerhardt knew some members of Wurtz's family, especially his uncle T. Kreiss, to whom he sent his regards. See letters of 9 January 1844 and 7 January 1855, Paris, Académie des Sciences, Don Tiffeneau, Dossier Gerhardt.

67- In his letter of 4 July 1844, Gerhardt seldom referred to votre éditeur (your publisher), suggesting that the decision to carry out this translation had been taken by Wurtz. Paris, Académie des Sciences, Don Tiffeneau, Dossier Gerhardt.

68- See Fruton, op.cit. (46) and HARRIS, J.; BROCK, W.H., "From Giessen to Gower Street: towards a biography of Alexander William Williamson (1824-1904)", Ann.Sci., 31 (1974), 95-130.

69- He presented to his examination a work entitled Sur les corps pyrogénés, Friedel, op.cit. (15), 10.

70- Like Deville , who remained Dumas's suppléant at the Sorbonne for 13 years, Wurtz also held the corresponding post at the Faculty of Medicine, but for four years.

71- The Musée Dupuytren was a museum devoted to pathological anatomy founded in 1835, and belonging to the Faculty of Medicine. Paris Médical. Assistance et enseignement, (Paris, 1900), p.69-70. This laboratory was apparently so inadequate that it may explain why Wurtz postponed until the summer his research on urea which he carried out in the laboratory of the department of pharmacy at Strasbourg University. See letter from Wurtz to Dumas dated 9 November 1848. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

72- Charles Dollfus (1828-1907) was born in Mulhouse, Alsace. He studied chemistry in Giessen and under Liebig's supervision he obtained his doctorate in 1846. He worked for Dollfus & Mieg Company, a family firm. Later he moved to different economic activities. especially tourism and hotel management. In 1881 he founded Dollfusville in Algeria. See Fruton op.cit. (46), 51. Also FOX, R. "Presidential address: science, industry and social order in Mulhouse, 1789-1871", B.J.H.S., 17 (1984), 127-128 (159).

73- François Verdeil (1826-?) was born in Lausanne, Switzerland, and took his degree in medicine in Giessen. Under Liebig's supervision he did his doctorate in chemistry (1848) and came to Paris in 1850. His research was devoted to physiological chemistry and in 1852-1853 he published together with Robin, a treatise on anatomical and physiological chemistry. See Fruton, ibid., 59.

74- See Chapt. 3 and Appendix 1.

75- Ibid.

76- Ibid.

77- Some of its members and particularly Foucault, Bréguet, Verdet, Robin and Serret with whom Wurtz maintained close friendship used to meet, before the meetings at the Café Procope to discuss scientific issues and academic policy. Friedel, op.cit. (15), 12.

78 FOUCAULT, L., "Feuilleton. Académie des Sciences", Journal des débats politiques et littéraires, (10 Jan. 1850).

79- Foucault pointed out:

> Le beau et nouveau travail que M. Wurtz a présenté il y a quelques temps à l'Académie peut-être considéré comme un essai enterpris dans la voie nouvelle que nous venons de signaler...le Mémoire de M. Wurtz restera dans la science comme un modèle. Ibid.

80- The recognition from the state was an important ingredient in the careers of the French savants.

81- See letter of 14 January 1850. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

82- See Chapt. 1, section 1.2.

83- It was re-established 25 years later.

84- Wurtz kept his duties of translator of chemical articles for the Annales de Chimie until 1872. Verdet was in charge of the articles on physics.

85- Dumas held the chair of chemistry helped by Wurtz. Simultaneously Orfila was professor of medical chemistry, a post he held for 30 years. At the death of Orfila the two chairs were combined and Wurtz succeeded to a chair whose new title was "chimie organique et minérale". CORLIEU, A. Centenaire de la Faculté de Médecine de Paris, 1794-1894, (Paris, 1896).

86- His élève Gautier mentioned that:

> Différent de son maître Dumas, dont le language classique et sobre s'élevait peu à peu d'une émotion contenue à l'expression magistrale...Wurtz au contraire, gagnait d'emblé son auditoire par le charme de son discours, la clarté de sa parole, la couleur de ses images, l'élégance de ses démonstrations, mais surtout par la conviction qui se dégage de toute sa personne.

GAUTIER, A. "Adolphe Wurtz", Rev. Sci., 34 (1884), 641-648 (646).

87- The emotions Wurtz put in his lectures were unexpected for a "serious" subject as science. As Friedel mentioned:

> Etonnant parfois ceux qui ne le connaissaient pas et que cette éxuberance inaccoutumé dans un cours de science troublait, mais qui revenaient aux leçons suivantes, captivés et charmés.

Friedel. op.cit. (15), 13.

88- Ibid., 77.

89- See Chapt.4.

90-WURTZ, "Sur la constitution de l'acide hypophosphoreux", Liebig Ann., 43 (1842), 214-234. This article was published as the result of Wurtz's experiments at Liebig's laboratory. It was also published in the following year in the Ann. Chim. [2], 7 (1843), 35-50. In this case and generally speaking we notice that the articles published in the Annales de Chimie corresponded to research carried out during the previous year to the date of publication. The second article on this subject "Recherches sur la constitution des acides du phosphore", C.R., 21 (1845), 148-155 and 354-360, was based on experiments performed in Dumas's laboratory.

91- As he detected the presence of hydrogen and oxygen, which corresponded to the constituents of water, at the time often represented HO, he began by supposing that these acids might be composed of water as such. His interpretation of the experiments, led, however, to a different conclusion.

92 Wurtz, op.cit. (80), (1845), 360.

93 As Wurtz mentioned:

> Ce n'est qu'en étudiant attentivement les sels que forment un acide, que l'on peut espérer de dévoiler sa véritable nature et l'arrangement intime. Ibid., 357.

94- WURTZ, "Sur l'hydrure de cuivre", Ann. Chim., [2], 11 (1844), 250-252.

95 Copper hydride was one of the few metallic hydrides known in this period.

96- LAURENT, A., "Recherches sur les combinaisons azotées", Ann. Chim., [2], 18 (1846), 266-298.

97- The electrochemical dualism of Berzelius only admitted that opposed polarities could result in a compound. Thus they were exclusively formed through the addition of one electronegative element or radical and an electropositive element or radical.

98- WURTZ, "Recherches sur l'acide sulphophosphorique et le chloroxyde de phosphore", Ann.Chim., [2], 20 (1847), 472-482.

99- In 1837 Liebig had suggested that ammonia was the type of all organic bases, since its hydrogen can be replaced by an alkali metal to form what he called an amide.

100- WURTZ, "Sur une série d'alcalis organiques homologues avec l'ammoniaque", C.R., 28 (1849), 223-226

101- WURTZ, "Recherches sur les ammoniaques composées", C.R., 29 (1849), 169-172.
This work was to be published in the Mémoires des savants étrangers, 11 (1851), 777-844.

102- Using substitution theory and Gerhardt's concept of homologous series, Wurtz contributed to the establishment of the ammonia type on analogical basis:

> Si l'on prend des composés hydrogénés les plus simples, l'ammoniaque, on peut remplacer dans cet alcali volatile une molécule d'hydrogène par une molécule de méthyle, d'éthyle, d'amyle... et l'on observe une série de composés qui ont une analogie frappante de propriétés avec l'ammoniaque elle-même. Ce sont des bases puissantes...je l'ai désignerai sous la dénomination générale d'ammoniaques composées.

WURTZ, "Mémoire sur une série d'alcaloïdes homologues avec l'ammoniaque", Ann.Chim., [2], 30 (1850), 443-507 (446).

103- As he mentioned :

> Tout ce que nous savons sur la manière dont les combinaisons organiques se dédoublent ou se transforment nous autorise à penser que dans un group composé formé d'éléments nombreux ces éléments n'ont pas tous, les uns à l'égard des autres, les mêmes rapports et la même affinité, qu'en un mot ils sont arrangés, disposés d'une certaine manière, et que cet arrangement ne saurait être changé sans que la combinaison elle-même en soit modifiée dans sa nature et dans ses propriétés...Quoiqu'on ai pu dire, découvrir cette constitution ce sera toujours un problème à résoudre.

Ibid., 444-445.

104- Notably in 1856 in his Traité de chimie organique, (Paris, 1856), vol.4, p.563, Gerhardt claimed that:

> C'est un préjugé généralement si répandu qu'on peut par la formule chimique exprimer la constitution moléculaire des corps, c'est à dire le véritable arrangement de leurs atomes, que peut-être, j'aurai de la peine à persuader du contraire. Les formules chimiques n'expriment et ne peuvent exprimer que des rapports des analogies.

105- See Chapt. 4, p. 168.

106 WURTZ, "Sur l'alcool butylique", C.R., 35 (1852) 310-312. These investigations were to be taken up in 1854.

107- See Chapt.4, section 1.

108 See p. 84 of this chapter.

109- See Chapt. 4 , section 1.2.10.

110- See Chapt.5, section 1.1.

111- See Chapt.5, section 3.

112- Barreswill (1817-1870) began his career as préparateur at Pelouze's laboratory. He taught chemistry at the Collège Turgot and at the Ecole de Commerce. Later he was appointed inspector of children's work in the factories, secretary of the Comité Consultatif des Arts et Manufactures and expert at the Ministry of Commerce. He published on analytical chemistry (1808), photography (1854) and the Dictionnaire de chimie industrielle, (1861-1864), in which Wurtz collaborated. He died during the Franco-Prussian war while he was in charge of collecting children to put them in safety in the cities threatened by the Prussians. FIGUIER, "Barreswill" L'Ann. Sci. Ind., 15 (1870-1871), 535-536.

113- Tiffeneau, Haller et al., op.cit. (2), 585.

114- See Chapt.4, section 2.1.6.

115- This Society had been created by L. J. Thenard to help the families of deceased savants.

116- WURTZ, "On oxide of ethylene considered as a link between organic and mineral chemistry", Journ. Chem. Soc., 15 (1862), 487-506.

117- See Chapt. 4, section 2.1.6.

118 For instance, Pasteur and Berthelot were only elected to the Royal Society several years after their election to the Académie des Sciences.

119- See, for instance, GILLES DE LA TOURETTE, G. "Adolphe Wurtz" Le progrès médicale, 12 (1884), 394-395 (395); VULPIAN in Procès verbaux de l'Assemblée des Professeurs de la Faculté de Médecine (2 Dec. 1875), Paris, Archives Nationales (AJ/16/6255*).

120- Between 1865 and 1875 as Doyen, and from 1875 onwards as Doyen Honoraire he cooperated with the administration of the faculty as adviser.

121- As Vulpian mentioned:

> En effet, c'est à lui qu'on doit la création de l'outillage scientifique de nombreux laboratoires qui n'existaient avant lui. Grâce à ses démarches, reitérées, le crédit affecté aux différents services de la Faculté ont été considérablement augmentés. Vulpian, loc.cit.(119).

Wurtz also published in 1872 a report to the Ministry of Public Instruction on the bad state of the buildings of the Faculty of Medicine, on a budget for a reconstruction and on the plans made by the architect Ginain. See WURTZ, "L'état des bâtiments et des services matériels de la Faculté de Médecine de Paris", Rev. Sci., 1-2 (1871-1871), 852-854.

122- The reasons why the ministry chose Wurtz to go abroad might have been his personal contacts and relationships, and his knowledge of foreign languages.

123- WURTZ, Les hautes études pratiques dans les universités allemandes, (Paris, 1870) and Les hautes études pratiques dans les universités de l'Allemagne, Autriche et Hongrie, (Paris, 1882).

124- Before the descriptions of foreign laboratories, Wurtz presented his own views about how a laboratory should be organised. But as Friedel mentioned:

> Wurtz y fait une peinture animé de ce que doit être un laboratoire moderne, avec son installation perfectionée et son travail en commun, mais par un triste retour, ce n'est pas en France qu'il a trouvé réalisé son modèle. Friedel op.cit. (15), 18.

125- Gilles de la Tourette, loc.cit. (119) mentioned that:

> Le nouveau Doyen ne permit jamais aux policiers de franchir la grille de son école, mais encore combien de fois n'alla-t-il pas lui-même arracher à la préfecture de police de malheureux étudiants qu'on avait arrêtés sous un prétexte futile.

Several of these incidents are also mentioned in the minutes of the Faculty as that which occurred involving Cazeneuve, an élève of Wurtz. See Procès-verbaux , op.cit. (119), (2 Feb. 1875).

126- Robin was a micrographer at the Faculty of Medicine.

127- Gautier, op.cit. (86),777.

128- The kind of arguments involved were of the following type, which referred to Miss Putnam, an American candidate:

> La femme étant mineure par le fait du mariage, échape à toute responsabilité personelle et que par conséquent l'adoption de la demande de Mlle. Putnam, pourrait entraîner de graves complications. Procès verbaux, op.cit. (119), (26 Nov.1867)

The group of women was formed by Mrs. Brès (French), Miss Putnam (American), Miss Garret (English), Miss Gontcharoff (Russian). See LIPINSKA, M., Histoire des femmes médecins, (Paris, 1900), p.413. As a curiosity Lipinska's work was accepted in 1900 as a doctoral thesis in Medicine in the Parisian Faculty.

As regards Miss Putnam , although never mentioned it seems that she might have carried out her experiments for her doctorate in Wurtz's laboratory because of the subject of her thesis Graisse neutre et acides gras. This gained her a bronze medal from the Faculty. See Procès verbaux , op.cit. (119), (7 March 1872).

129-Wurtz appealed twice to Duruy to decide on behalf of Miss Garret, both for her diploma and for her doctorate. See Lipinska, op.cit. (128), p. 116.

130- The impact of Wurtz's attitude was revealed by the presence of organised groups of female students of the Faculty of Medicine and of the Sorbonne at his funeral. See Friedel, op.cit.(15), 33.

131- See, for instance, FIGUIER, L., "Alexandre Boutlerow", L'Ann. Sci. Ind., 30 (1886), 595-596 (596).

132- Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

133- See Chapter 5, section 3 and Appendix 1.

134- Pasteur mentioned in a letter to Raulin sent on 10 March 1868 that he was particularly pleased that Wurtz had been appointed his temporary suppléant:

> Je partirai tout prochainement. C'est M. Wurtz qui a bien voulu se charger de me suppléer. Ce choix excellent me laisse moins de regrets en ce qui concerne mon cours et mes auditeurs.

VALLERY- RADOT, Correspondance de Pasteur, (Paris, 1951), vol. 1 p.367-368.

135- See Gilles de la Tourette, op. cit., (119). While carrying out this post, he was asked to find the dead body of Regnault's son. Friedel, op.cit. (15), 24.

136- See Friedel, op.cit. (15), 24.

137- FRIEDEL, C. "Notice sur la vie et les travaux de R.D. Silva", Bull. Soc. Chim. Fr., 3 (1890), 1-19 (15).

138- See Procès verbaux, op.cit. (119), (10 Sept. 1870).

139- See Chapt 5, section 1.2.

140- Friedel, op.cit. (15), 20.

141- When Wurtz resigned he had achieved as dean the creation of the chemical laboratories of the L'Hôtel Dieu, of the Pitié and Charité, and obtained the reconstruction of the Ecole Pratique. See Gilles de la Tourette, op.cit. (119).

142- See Friedel , op.cit. (15), 20. Also in a letter he addressed to Butlerov Wurtz mentioned:

> Je fais en ce moment un cours de chimie organique à la Sorbonne où les nouvelles idées ont tant de peine à pénétrer. J'espère que mes efforts contribueront à amener ce résultat désirable et à secouer l'esprit de routine et la torpeur de quelques uns de nos professeurs français.

JACQUES, J.; BYKOV, G.V., "Deux pionniers de la chimie moderne Adolphe Wurtz et Alexandre M. Boutlerov, d'après une correspondance inédite", Rev. Hist. Sci., 13 (1960), 115- 134 (128).

143- See Chapt. 4, section 2.1.9.

144- See Chapt. 5, section 3.

145- The Faraday Lecture used to take place every three years in the Royal Institution. Only foreign scientists could be invited and awarded the corresponding medal. The immediate predecessors of Wurtz had been Dumas (1869), Cannizzaro (1872) and Hofmann (1875).

146- Friedel, op.cit. (15), 28.

147- WURTZ, "La théorie des atomes dans la conception générale du monde", Rev. Sci., 7 (1874), 170-177. See Chapt. 5 on the AFAS.

148- As it was typical of the 19th century Wurtz, on other occasions, advocated clearly a historical approach emphasising continuity that he, however, applied rather to ideas than to achievements:

> Les idées actuelles se rattachent aux idées anciennes; elles se sont fait jour, non par une révolution subite, mais par un progrès lent et continu.

WURTZ, Leçons de philosophie chimique, (Paris, 1864), p.1.
It should be added that the historical dimension is itself a strong feature of the discourse of the savants of the 19th century. In the case of Wurtz it operated at two levels: one is the history of the subject itself, the

other regards the presentation of research articles, which was conditioned by the theoretical framework that implied the establishment of genealogies of compounds. Thus, each compound had its own chemical "family" history as in the "Histoire générale des glycols", for instance.

149- Wurtz, op.cit. (147), 170-171.

150- Ibid., 170.

151- Pasteur, for instance, before the Franco Prussian war (1868) was advocating that France should regain its scientific superiority, and follow the example of German universities. But, after the war these claims became more emotional:

> C'est qu'il faut travailler par tous les moyens possibles à assurer dans un prochain avenir la supériorité scientifique de la France.

See VALLERY-RADOT, (edit.), Œuvres de Pasteur, (Paris,1922-1939), vol. 7, p.199-201.

152- Mary Hesse pointed out that Bacon was often misinterpreted. His methods had been seen as merely empirical and its aspects towards theoretical system-building were often dismissed. HESSE, M., Article Francis Bacon, D.S.B. , vol.1, p.372-376.

153- Ibid.

154- Wurtz, op. cit. (147), 170.

155 Ibid.

156 Ibid., 171.

157 Ibid.

158- Ibid.

159- Ibid., 172.

160- As he claimed:

> Et c'est là, messieurs, la vraie méthode en chimie: déterminer la composition des corps, et par l'analyse attentive de leurs propriétés fixer, autant que possible, le groupement de leurs dernières particules. Ibid., 172.

161 Ibid.

162 As he mentioned:

> Déduire les transformations des corps de leur structure moléculaire et à créer, par une sorte d'intuition, de nouvelles molécules à l'aide de celles qu'on connait déjà. Ibid., 174.

163- Ibid.

164- Ibid.

165- Ibid.

166- Ibid., 176-177.

167- Ibid., 177.

168- Ibid.

CHAPTER 3 - THE ELEVES OR THE FOLLOWERS OF THE MAITRE.

1. Some remarks on the identification of the élèves.

As mentioned in the introduction, the word élève had a particular meaning in the French context of the mid-19th century. Basically, the élèves were potentially the imitators of the maître , i.e., they were supposed to be the followers of the système he advocated and were commonly under his patronage. Thus either one of these situations individually, or a combination of both will emerge from the analysis of Wurtz's élèves. This analysis will be carried out consistently with the basic assumptions put forward in the introduction, and consequently the consideration of the élèves will also be framed both by the concepts of école and of maître as they have already been given.

The identification and specification of the way in which each élève was an élève inside this particular école has, however, often proved difficult. As the French research laboratories were an informal organisation within the system of higher education, no official records may be expected to be found. In addition, Wurtz's private records and a great part of his private correspondence have been lost[1]. Hence, different but complementary procedures had to be used.

First of all, for the consideration of Wurtz's élèves the starting point was the list provided by Friedel of about 120 names, in his obituary of Wurtz. From this list, about 110 had signed as élèves the pedestal of a bronze statuette full of symbolic meaning since it was a reproduction of Bernard de Palissy[2] by Barrias, which was presented to Wurtz in 1881, when he was elected to the Senate by the centre left wing of the Republican party. The remaining élèves listed were according to Friedel, unable to subscribe to this sculpture for several reasons such as difficulties in communication between Paris and their respective locations, and he added that this large number was far from being complete[3]. This claim is reinforced if we take into account a letter Wurtz addressed to Dumas in 1864[4] in which he stated that he felt honoured by having associated with his école more than 90 élèves, whose papers had appeared regularly in the Comptes Rendus, Annales de Chimie and other journals. Accordingly, in addition to the above list, those mentioned by Wurtz in his correspondence as his élèves are taken into consideration in this thesis, as well as those who were neither listed by Friedel nor mentioned in Wurtz's correspondence, but acknowledged Wurtz or his laboratory in their research papers.

All those who either saw themselves as Wurtz's élèves or were seen in that way by Wurtz himself, or by their colleagues are presented in **Table I** (Appendix 1). Thus, no a priori categories have been imposed on them in an attempt to classify the élèves. Instead, these will emerge a posteriori and are to be taken as artificial, but convenient groupings.

In order to obtain general information about each élève, a systematic search for obituaries in scientific journals was also carried out. Often these obituaries were written by a former colleague of the deceased at Wurtz's laboratory, and cross references to other élèves are found easily. For the cases of well-known chemists, both the D.S.B.[5] and standard books on history of chemistry were consulted as well as other secondary literature. Also a list of doctoral theses completed in France during the 19th century[6] and the references found in a history of the Société Chimique de France[7], together with lists of staff belonging to the Faculty of Medicine[8] were used.

For the purpose of evaluating the participation of the élèves in chemical investigations a search was made in the Royal Society Catalogue,[9] although it often does not give an absolutely complete list of the articles published by each of the élèves. A similar procedure was applied to the Poggendorf's Biographisch-Literarisches Handwörterburch[10], which had the further value of providing some biographical notes. This was followed by a systematic search for acknowledgements to Wurtz, through the papers under the above names, but others were also found. This search was mainly carried out through pages of the Comptes Rendus, Annales de Chimie and Bulletin of the Société Chimique, but it has to be considered that several élèves published in foreign journals, which were not available to me in order to check possible acknowledgements. A remark on these acknowledgements should also be made. Although the manner in which the acknowledgements were expressed may be considered relevant, they cannot be taken as a measure of the grade of attachment to Wurtz's école. Generally speaking, instead of obsequious acknowledgements as was common in the days of Dumas, we may say that the formula "these investigations were carried out at the laboratory of Mr. Wurtz"[11] was generally adopted. This may be explained in various ways. On the one hand the tradition inaugurated by Liebig in Germany and Dumas in France had contributed to make a training period in a research laboratory a more common practice. On the other hand, the fact that the élèves were paying a fee to cover training costs together with the relatively independent basis on which they could carry out their investigations made obsequious acknowledgements inappropriate. At this point it seems that what really mattered was to make known the connection of a piece of research produced by a newcomer and his maître, for the sake of their professional careers.

Although they became increasingly exceptional, some detailed acknowledgements may, however, be found. These few examples occurred especially between 1853 and 1857, when Wurtz had just been appointed professor of the Faculty of Medicine (1853) and just starting his école on a more permanent basis. Even so, this kind of open manifestation of gratitude was associated with a particular situation of favour[12], when a particular élève was for some reason exempted from the payment of the fee. Finally, there are cases of total absence of acknowledgements, which may be due to several reasons: for example whenever the connection between the élève and Wurtz had been made in previous papers[13] and had become well known in a wider context or when it involved foreign chemists who already held academic posts abroad of some seniority at the time[14]

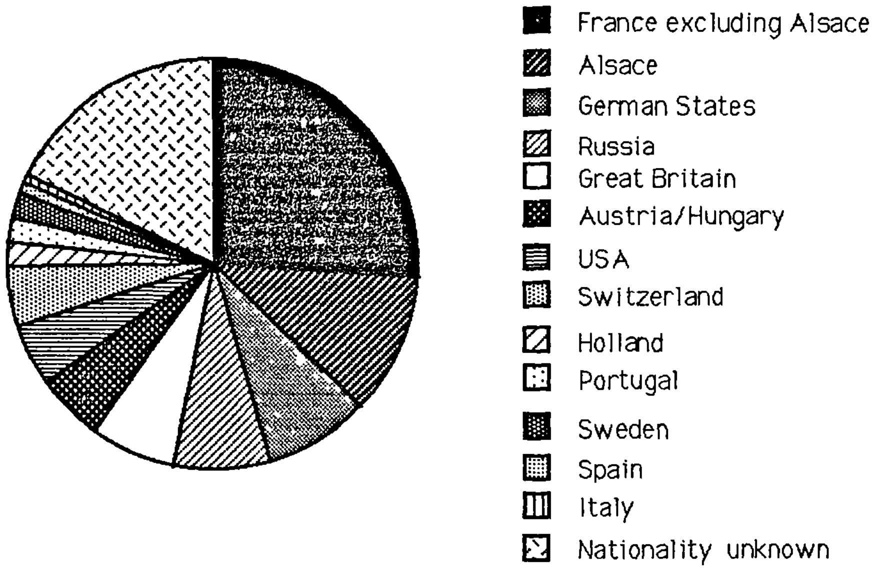
2. The élèves.

With all the data collected as mentioned above, a table was built up in which a basic identification of the élèves is provided. Also the time they spent in Wurtz's laboratory, the number of research papers and related research areas are presented in chronological order.

From the data collected in **Table I**, (Appendix 1) several conclusions may be drawn. Making use of a pie chart representing the nationalities of the élèves, we conclude that in general terms the total number of foreigners who attended Wurtz's research laboratory was greater than that of the French trainees and also approximately one third of the latter were

Alsatians.

Chart showing nationalities of <u>élèves</u>



Among the foreigners the countries most represented were the German states and Russia, followed by Austria/Hungary, Great Britain, Switzerland and the U.S.A.[15]. Using data included in **Table I** it is also possible to assess the number of admissions and departures per year, as well as the number of <u>élèves</u> at work each year. Here a remark should be made as regards the time the <u>élèves</u> spent with Wurtz, which varied from about two months to the extreme of 30 years. This factor was obviously taken into account to determine the number of <u>élèves</u> working in the laboratory each year. It is particularly difficult, however, to draw conclusions from the available data, between 1854 and 1864. In fact, taking into account Craft's testimony referring to 1854, when Friedel entered the laboratory,

> There were some sixteen places, of which usually one third were occupied by foreigners, particularly Russians, Germans, Austrians, Italians.[16]

If we also consider the letter Wurtz addressed to Dumas in 1864, in which he claimed to have had about 90 <u>élèves</u>, we immediately see that our data is quite likely to be far from being complete. Indeed, the number of <u>élèves</u> between 1854-1863, whose names were available corresponded roughly to one third of the 90 Wurtz mentioned. But, looking at the second and third decades, 1864-1873 and 1874-1883, and since the reputation of the <u>école</u> was established and maintained, it seems that the number of <u>élèves</u> in training was not affected by any external factor: between 1857-1866, there were about 15 élèves on average each year, which corresponded to the capacity of the laboratory, and between 1866-1874, 20-25 on average. Thus, neither what could be envisaged as important scientific achievements nor events such as the Franco-Prussian war interfered in the number of élèves admitted, but merely the availability of space. Especially from 1866 onwards, an increase in the number of élèves is noticeable. This may be explained by a process of "decentralisation", which took place, notably when Friedel was given a laboratory at the Ecole des Mines (1866) and when Gautier became director of the laboratory of biological chemistry (1874) created by Wurtz, while Dean of the Faculty of Medicine. Many of the élèves of Friedel and Gautier presented themselves also as élèves of Wurtz and often attended and acknowledged his laboratory .

Back again to Table I, as regards publication, about 72% of the élèves published exclusively under their own names, 37% with other élèves and 6% published joint papers with Wurtz[17], while they were attending the laboratory. In this respect Wurtz did not follow the example of Dumas, who generally appeared as co-author of the articles of his élèves. The articles produced by Wurtz's école covered several areas of research, but their relative importance varied throughout the years. Until 1853, pure organic chemistry was not a main study of the élèves at the private laboratory that Wurtz and his associates Dollfus and Verdeil established. Despite being the scientific director of this enterprise, Wurtz seemed to have shared the supervision of the élèves with Verdeil and consequently the definition of the research topics. Thus, apart from Wurtz's own work the investigations carried out at the private laboratory were basically devoted to practical questions, notably the isolation of compounds of pharmaceutical interest, physiological chemistry, and analytical chemistry applied to agriculture, which to some extent followed Liebig's pattern. Only after Wurtz established his own laboratory at the Faculty of Medicine (1854), did research become clearly devoted to pure organic chemistry, which is explained by the fact that organic chemistry was, at this point, beset by conflicting views and theoretical consolidation was desirable, as it will be seen in the next Chapter.

Although organic chemistry was always prominent through the years its sharp dominance as a research area for the élèves became gradually less marked, especially after 1864. From this time onwards the research areas in which the élèves were involved became more diversified. Thus more investigations on mineral chemistry were developed particularly due to Friedel's contributions and consistently with Wurtz views on the unification of chemistry. Spectroscopy also became an issue of concern for some élèves, since its importance as an auxiliary method for chemical research was perceived and its implementation was associated with the implications of atomic theory. In addition, research on physical chemistry was also carried out, especially as a tool for the establishment of physical parameters of chemical species. Often associated with physical and analytical chemistry was the development of techniques, apparatus and instruments. Biological and medical chemistry appeared as an independent area of importance particularly after 1874.

Applied chemistry as such was not a strong point at the laboratory of the Faculty of Medicine, but rather in other laboratories and by the élèves directly involved in the industrial sector. But this fact is not inconsistent with Wurtz's ideas. In fact, for him in theory the dichotomy between pure and applied chemistry did not exist[18]. This integrated vision of application seems to have been assumed by several of his élèves, as for instance Scheurer-Kestner, Lauth, Le Bel and Tcherniak, from the early times until the last years of Wurtz's research laboratory. As an example, the case of Scheurer-Kestner may be singled out. After leaving Wurtz's private laboratory he carried out his investigations at the laboratory of his factory. Yet he remained closely attached to Wurtz throughout his life, coming to him often to get advice and collaborating intensively in the goals of the école. As an industrialist, his research was to become fundamentally devoted to what may be seen as applied chemistry, but which he did not isolate from theoretical questions. Notably he published in 1862 a book entitled Principes de la théorie des types, and in a paper published in 1861 he corroborated Wurtz's views on the atomicity (valency) of iron, while doing experiments of industrial interest.

3. Organisation: division of labour and the "hard-nucleus".

The emergence of certain specialties within Wurtz's école, especially among the more permanent élèves suggests the existence of a certain amount of division of labour as far as research was concerned, which was also reinforced by the nature of the principles chosen by Wurtz to underlie his research programme, as we shall see in next Chapter. But division of labour also becomes apparent from the analysis of the involvement of the élèves in a wider context, both as regards institutions and editorial activities, which were launched either by Wurtz with the support of his élèves or the other way around. Thus **Table II** (Appendix 1) is intended to summarise the institutional involvement of the élèves and **Table III**, their editorial engagements.

The characteristics of these institutions are to be analysed in Chapter 5, but from the analysis of **Table II** we may conclude that the majority of the élèves of Wurtz after 1857 were members of the Société Chimique de France as if membership in Wurtz's école implied almost automatically membership of the Société. The special commitments and offices within the Société, however, were restricted to the élèves residing in France, who later acquired a certain status within the scientific community either through academic positions or posts related to industry. Concerning the Association Française pour l'Avancement des Sciences membership was reduced more or less to the élèves residing in France.

In **Table III**, the involvement of the élèves in editorial activities, especially in the Bulletin de la Société Chimique de France, in Wurtz's Dictionnaire de Chimie Pure et Appliquée and Agenda du Chimiste are given. Although in this table only those with an editorial status are mentioned we may say, in addition, that a great number of Wurtz's élèves collaborated in the Bulletin by contributing articles and also in the case of the visiting foreigners this collaboration continued after they had left Paris. To a small extent the same may be said about Wurtz's dictionary.

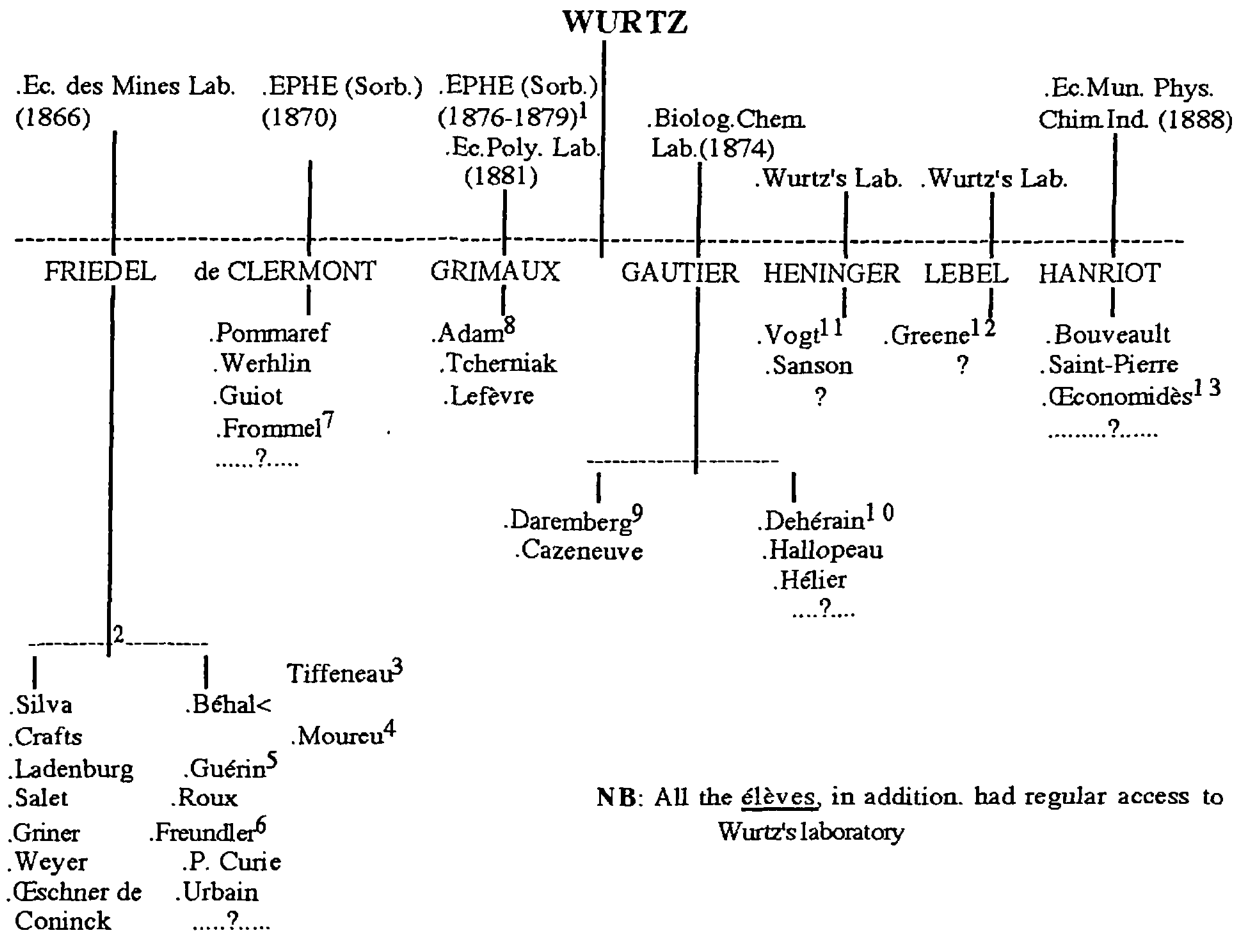
From the **Tables I, II** and **III** we conclude that the greatest involvement in research and activities in a wider context was chiefly associated with élèves who resided in France and gradually built up a career as academics or industrialists, remaining closely linked to Wurtz for a great part of their lives. Thus, in **Table IV** (Appendix 1) these careers are summarised, in terms of professional posts, scientific recognition, and power relating to both their professional status and membership in the Académie des Sciences.

From this table several conclusions may be extracted. Thus doctorates were not a main goal for Wurtz's école if we consider that, in addition to the élèves mentioned in **Table IV** who resided in France, only two[19] of the foreigners obtained their doctorates while attending Wurtz's laboratory. This academic degree was only sought by those who wished to follow academic careers in France. Even so it was not envisaged as a priority since often the élèves submitted their theses a long time after having initiated their chemical investigations and, consequently, with a considerable number of papers already published. Indeed, in the case of Wurtz's élèves doctorates emerge rather as a formality required by the academic posts than as an important aim either for the élèves or for the école itself. In this way Wurtz's école contrasted fundamentally with those of Deville and Berthelot, and especially the école of the latter, the prospect of a doctorate seemed to have been the major means of attracting élèves[20]. Even for the foreigners, who attended the laboratory for one or two years, obtaining a doctorate was not their goal, as we shall see later on.

Regarding prizes, the Jecker Prize of the Académie des Sciences, which rewarded research on organic chemistry had been frequently given to Wurtz's élèves and according to the following proportions per decade: 60% (1859-1870), 56% (1870-1880), 60% (1880-1890)[21]. In relation to membership of the Académie des Sciences, four élèves were elected as well as two corresponding members, much less than with Deville's école[22]. Some of Wurtz's élèves, however, expressed their criticisms of the Académie des Sciences and did not consider presenting their candidacies because they found the election procedures humiliating[23].

An important issue concerning Wurtz's élèves mentioned in the **Table IV** (Appendix 1) was undoubtedly the academic posts they held, which in a significant number of cases implied the allocation of research laboratories and, in some of the others, physical proximity to Wurtz's laboratory. In this context the process of "decentralisation" becomes clearer. Notably in relation to those who shared Wurtz's research responsibilities, involving supervision of élèves and, as a consequence, an "academic genealogy" may be defined as illustrated in the **Diagram** in the next page:

Diagram illustrating the "academic genealogy" of Wurtz's <u>élèves</u> generated by the process of "decentralisation"



NB: All the <u>élèves</u>, in addition. had regular access to Wurtz's laboratory

1- Grimaux left the laboratory of the Ecole Pratiques des Hautes Etudes(EPHE) at the Sorbonne due to incompatibility with the director Riban, an <u>élève</u> of Berthelot, and returned to Wurtz's laboratory.

2- These names were engraved on a bronze plate presented to Friedel in 1888 by his <u>élèves</u>. The names on the left side are of those who considered themselves both <u>élèves</u> of Wurtz, acknowledging his laboratory, and of Friedel.(See Hanriot's obituary of Friedel in general bibiliography).On the right are those who became Friedel's <u>élèves</u> after Wurtz's death.

3- Tiffeneau is a good example of how the value associated to the <u>système</u> of Wurtz was transmitted until the third generation. He expressed his admiration for Wurtz, Grimaux, Scheurer-Kestner, and he published Gerhardt's correpondence.

4- Moureu is another good example of transmission of values, this time associated with internationalism. He attended both Béhal's and Friedel's laboratory, and he prepared his doctorate with the latter. Like Wurtz, Friedel, and Combes, who participated in international meetings seeking international consensus over formulae and notation, Moureu founded the IUPAC (International Union of Pure and Applied Chemistry)

5- Guérin and Roux portray the good relations between some of Wurtz's <u>école</u> and Pasteur's. Pasteur, in particular admired both Wurtz and Friedel.

6- Freundler entered Friedel's laboratory in 1893. Here he met LeBel, who visited Friedel regularly and a friendship was established. Later he became manager of LeBel's Foundation.

7- This list of <u>élèves</u> of de Clermont is not exhaustive, and those included never claimed to be Wurtz's <u>élèves</u>. However, among the non identified <u>élèves</u> of Wurtz, we may consider that some may have been trained by de Clermont, but it was impossible to check.

8- Both Adam and Tcherniak considered themselves <u>élèves</u> of Wurtz and acknowledged Wurtz's laboratory in some of their papers.

9- On the left side are those who considered themselves <u>élèves</u> of Wurtz and acknowledged his laboratoty. On the right, those who never acknowledged his laboratory.

10- Dehérain and Hallopeau collaborated as editors of the <u>Bulletin</u> of the Société Chimique and in Wurtz's dictionary.

11- Vogt also considered himself Wurtz's <u>élève</u> and published with him a joint paper.

12 and 13 - Also <u>élèves</u> of Wurtz.

Thus, the **Diagram** suggests that the family metaphor, which was currently associated with the concept of école in France had a particular meaning in Wurtz's école. This is especially revealed by those élèves of senior élèves like Friedel, Gautier, Grimaux etc., who also considered themselves as élèves of Wurtz, as if a kinship relation was involved. Thus, respect and veneration towards Wurtz, his ideas and moral values was passed onto subsequent generations, apparently including those who did not conform easily to the rules of the establishment of which Wurtz became a part. Le Bel, who had the reputation of having a difficult and independent personality, and Lecoq de Boisbaudran provide good examples, according to the testimony of Urbain:

> Charles Friedel[24] to whom I was préparateur, Le Bel and Lecoq de Boisbaudran who, since my youth honoured me with their friendship, taught me to venerate Wurtz, given the deep admiration they devoted to their maître.[25]

In this "genealogy" the way in which Wurtz acted as the guardian figure, the ancestor, whose charismatic power had been reinforced particularly by the respectability associated with his research, age and position, had two facets: on the one hand the transmission of the système through subsequent generations, on the other, the means of exerting power and patronage.

The transmission of the système advocated by Wurtz through his immediate followers until the third generation[26] was also to be revealed in practice by Tiffeneau, who published Gerhardt's correspondence, and Moureu. Notably the foundation of IUPAC by the latter followed the line of Wurtz's active involvement in the Karlsruhe meeting (1860) in which several of his foreign and French élèves[27] participated. It was continued by Friedel[28] and Combes[29] as members and champions of international commissions for the establishment of consensual norms for chemical nomenclature.

Wurtz's heritage and that of his immediate followers was also continued by their successors in the management of the Société Chimique, in the edition of both the Bulletin and Wurtz's dictionary, after his death. In order to ensure the efficient continuation of the école it was important for Wurtz to choose direct successors. Accordingly, Gautier was appointed to the laboratory of biological chemistry by Wurtz in 1874; Henninger, one of Wurtz's favourite élèves, was to be his successor at the laboratory of chemistry of the Faculty of Medicine[30], when the maître was still alive and planned to move to the new laboratories of the Sorbonne in the 1880s. Finally, with the support of the école[31] Friedel succeeded Wurtz as the head of the école at the Sorbonne[32] when the latter died in 1884. This choice was justified by the école not only on the basis of Friedel's scientific prestige but also on the imperative of continuing the Alsatian tradition.

As far as patronage is concerned, if the link of a chemist's career to the name of Wurtz might have had a great importance for the affirmation of the credentials of the élèves of the second generation, it did not mean that the power of patronage was exclusively concentrated in Wurtz's hands. In fact, it seems that decentralisation also extended to patronage, since Wurtz did not act necessarily as an intermediary. These senior élèves were able to use their personal influence and personal relations for patronage purposes and, as far as Dumas was concerned, they addresssed him as directly as Wurtz[33].

With all the elements presented so far we may conclude that some of Wurtz's élèves shared with the maître the practical aspects of running the école, which implied tasks such as research supervision, institutional involvement and editorial activity. Moreover, in this context, they were able either to exert patronage directly or to add individual initiatives to the école, which Wurtz welcomed[34]. This implied that in terms of organisation the école was based on a collaborative vision of work, and given the financial contribution to laboratory expenses from the majority of the élèves, as well as the decentralisation of power and responsibilities above mentioned, we may say that the model of organisation of the whole école transcended the typical family-like structure and was rather that of a society. Thus, every member had to contribute money, and their profit was predominantly of an intellectual nature especially for the foreigners, who saw their training as a part of an educational process. For the French the professional implications were more directly relevant. The management of the activities was carried out by a group of élèves, residing in France, which for the purposes of this thesis will be designated as the "hard-nucleus". By hard-nucleus is meant those élèves who remained attached to Wurtz over a long period of time. Although not permanently in his laboratory, but developing research in others associated with their posts[35] they shared with Wurtz a great part of the activities in which the école was engaged inside and outside the laboratory, ensuring in this way the maintenance and growth of the école and adding to its prestige. As an artificial classification the establishment of the hard-nucleus should not be understood as rigid and other élèves could have been included if more information about their role was available. These members of the hard-nucleus, in addition, may be divided into two categories: those whose occupations were linked to industry - the industrial wing - and those who held academic posts - the academic wing.

The élèves of the industrial wing were industrialists and usually belonged to families of Alsatian industrialists, since in the 19th century industry was largely regulated by genealogical patterns. After their initial period of training under Wurtz's direct supervision, their further personal research was not usually carried out in Wurtz's laboratory, but in the laboratories of the factories where they were working. However, they remained closely attached to him and to the système advocated by the école, both as regards scientific principles and activities in a wider context.

The élèves of the academic wing usually did not have family backgrounds related to industry, but of other kinds. They often remained attached throughout their lives to Wurtz's laboratory in one way or another. Despite the fact that some of them were allocated laboratories associated with their academic posts they often continued to use the laboratory of the Faculty of Medicine, although not on a permanent basis. These, together with those who permanently remained at Wurtz's laboratory during his life, shared with the industrial wing the same type of commitments as far as the école was concerned.

In order to understand what kind of reasons bound together the members of the hard-nucleus it is worth analysing its social composition as well as the religious, cultural, and ideological factors, which may have encouraged their association.

4. The main features and social composition of the "hard-nucleus".

In Table V (Appendix 1) the characteristics of the élèves of the hard-nucleus embodying both wings are displayed. The presence of an influential social group within the hard-nucleus- the Alsatians - becomes immediatley apparent. Besides a wealthy background, generally these shared a common bilingual education acquired at the Gymnasium of Strasbourg, which, as mentioned, was immersed in the local Protestant tradition. As Alsatians they associated with their province a particular idea of savant, of which they were extremely fond, that emphasised Romantic features and allied easily and openly metaphysics with empiricism. As an example, when referring to Wurtz's friend Schützenberger, his élève Lauth mentioned:

> He (Schützenberger) had those qualities that so often are associated with the sons of Alsace: a lively imagination which leads the spirit to the most demanding philosophical problems, implying both theoretical speculations and the formulation of hypotheses, whose resolution requires careful laboratory work...These were the attributes which also characterised Gerhardt and Wurtz, who like Schützenberger were children of Strasbourg.[36]

These peculiarities were apparently well known, defining somehow a style, which went beyond the French frontiers, as the testimony of the Italian chemist Cannizzaro demonstrates, when he referred to Gerhardt, Wurtz, Schützenberger and Friedel:

> There is a striking feature that cannot be ignored by historians of science, which is the contribution from Alsace to the scientific splendour of France, through four of the most productive and original chemists. These chemists, who enriched the scientific literature of the second half of the 19th century, were from Strasbourg and received their education there [37]

In fact, the Alsatians were linked by a cultural common background, that seems to be associated with their education in the Protestant Gymnasium and the social and intellectual movements of their home region. These absorbed many of the trends of German Romanticism and, as mentioned in the previous chapter, throughout the 19th century the promotion of social reforms leading to public welfare with emphasis on education, and the ideal of a cosmopolitan scientist-artist were particularly advocated. Thus, besides their membership in the Société Industrielle de Mulhouse the links of the Alsatians residing in Paris with their region and its current movements, were expressed also in their personal engagements in a wider context, notably as in the cases of Scheurer-Kestner and Lauth. The former ,who was to become later a politician and Senator, introduced into Alsace measures to improve social welfare of the working class[38], the latter, while a member of the Conseil Municipal de Paris, implemented services for public welfare related to health and education. Among these, he particularly emphasised the creation of a service of travel grants for post-graduate students, which was destined to encourage further training and original research[39].

But the weight of the Alsatians and their capacity for mobilisation within the hard-nucleus was to show itself in two of their engagements in a wider context, in which other non-Alsatians of the hard-nucleus fully participated. These initiatives were the foundation of the Ecole Alsacienne (1871) and the Ecole de Physique et de Chimie Industrielles (1882). The main features of these institutions are to be given in Chapter 5 but the involvement of the members of the hard-nucleus is summarised in **Table VI** (Appendix 1). In addition, they also engaged in individual and collective publications, which included text books embodying the theoretical principles advocated by the école, books on applied chemistry and analytical techniques, books and articles on history and popularisation of science to which was added their involvement in the Universal Exhibitions, especially in matters related to applied science.

Another characteristic which is especially striking among the Alsatians of the hard-nucleus, although not confined to them, was the emphasis they placed on their respective artistic and literary abilities, which many of them seem to have cultivated. But, if these features had already been stressed in their descriptions of Wurtz, the obituaries they wrote about their colleagues at Wurtz's laboratory almost defined a particular style by always giving an important place to these matters[40]. This emphasis on artistic inclinations did not find any parallel in the obituaries of the élèves of the other French écoles with the exception of that of Cahours. In fact, if the other savants-apprentices possessed them, they were absent from the descriptions of their lives, since their obituaries emphasised almost exclusively the relation between their moral integrity and their complete and nearly religious devotion to science.

In addition to these social, educational and cultural aspects which linked the members of the hard-nucleus of Alsatian extraction one of major importance was undoubtedly the religious factor, i.e. Protestantism. Yet, it was not confined to the Alsatians, but was present in those, who by faith or kinship associated with them, adhering to some aspects or initiatives related to French Protestant culture. Thus, religion became an important factor by uniting the elements of the hard-nucleus in different ways, since the Protestants or those in some way related to Protestantism belonged and moved within a minority of French society. Although at this stage of French history persecution already belonged to the past, and strong forms of discrimination to a more recent past,[41] yet subtle discriminating attitudes were still in practice as the statuette of Bernard de Palissy presented to Wurtz by his élèves seemed to suggest. Crafts in his memorial lecture devoted to Friedel provided an indicator of this state of affairs:

> Isolation is a too strong word to be applied to Protestant society at Paris and yet in certain ways their habits of thought are different from those of their neighbours... No memories of persecutions haunted the immediate past of the Alsatian Protestants... nevertheless, a mental barrier is raised to some extent between Protestants and Catholics, and curious testimony of this attitude was lately offered when the latter joined an army of Freethinkers and affected to confound the Protestants with Jews. Not religious controversies, but different habits of thought as marked as racial characteristics make a distinct although faint line between general Parisian society and that in which Friedel moved.[42]

We notice that the Alsatians and Protestants as members of a social minority, instead of isolating and converting the école into a closed community adopted instead an open attitude. Their openness allowed them to incorporate éleves with different backgrounds, whether or not belonging to other minorities, and notably people easily marginalised due to some unconventional feature, both inside and outside the hard-nucleus. This attitude also allowed the massive incorporation in the general activity of the école of foreigners, who were not excluded from its heart, the hard-nucleus. Associated in this way, these élèves were able to amalgamate launch and share initiatives but, above all, they shared the possibility of expressing their individual views and affirm themselves both in the scientific community and in French society. As a kind of microcosm of the whole école the hard-nucleus projects in this way an image of the pluralism and cosmopolitanism which were one of the most striking features of this école.

5. The visiting élèves.

Indeed the hard-nucleus may be seen in many respects as a micro world, since its members portray on a reduced scale a set of features also found in others who joined Wurtz's école temporarily. The majority of the élèves were foreigners and **Table VII** (Appendix 1) summarises some of their characteristics. From this table several conclusions may be drawn for different nationalities. Thus, when the Russians came to Wurtz's laboratory the majority were already familiar with Gerhardt's type theory, since they had studied either with Zinin as Butlerov did, or with Butlerov himself. Before coming to France the Russians usually attended German universities due to several educational and cultural affinities. As regards education, during the first quarter of 19th century the public schools of the Catherinean era had been transformed into German type Gymnasia, and this transformation was particularly effective in the Baltic states, Moscow, St. Petersburg and in Kazan[43]. By 1833, underlying the education provided by the Gymnasia was Schelling's philosophy and particularly the notion of uniqueness of individual cultures. The influence of German Romanticism was dominant in Russian culture and Naturphilosophie was the most important trend in science. Notably by the 1820s Schelling was one of the most read philosophers[44]. The French influence in Russian culture was, in the 19th century, largely confined to political theory and humanities and it is claimed that the only philosopher that both natural and social scientists could agree on was Francis Bacon[45].

Like the Russians, both Germans and Austrians prior to their arrival in Paris generally attended German research laboratories, where they obtained their doctorates, since the bureaucracy associated with the conferral of this degree in France represented a major sutmbling-block for foreign potential candidates. Thus, in Germany, they often became acquainted with similar theoretical principles to those advocated by Wurtz, notably the atomic theory, while they attended research laboratories such as that of Kekulé. Russians, Austrians, and Germans usually followed academic careers after leaving Wurtz's laboratory and often established research laboratories afterwards.

Among the British, the English were often already engaged in academic careers when they went to Paris and, usually, they either were Williamson's assistants or Hofmann's and thus familiar with Gerhardt's type theory and atomic theory. The Scottish went first to Germany as what emerges as a natural complement to their broad education[46] acquired in Glasgow or Edinburgh, which shared, in practice, some features with German universities, according to Helmholtz[47]. As regards the Irish, the single known case is that of Maxwell Simpson, who like the majority of British élèves, engaged in an academic career. In addition, the majority of the British élèves moved, after leaving Wurtz's école, to different areas of scientific research, notably applied physics and engineering, which was in tune with British tradition more devoted to application and especially mechanical engineering. As regards the Americans, they usually went first to Germany and then usually followed careers in industry after their departure from Paris.

From **Table VII** (Appendix 1) we may also conclude that Wurtz's laboratory was integrated into a network of research laboratories and for the majority of these élèves was the final point in an international line of research training. Particularly the Germans considered it as a "laboratory for final improvement"[48] and, as such, for the majority it was the last stage of their education, before starting their careers, usually as university scholars. The fee that the foreign élèves had to pay was naturally accepted as it was by the French élèves of Wurtz, since as indeed in the German states and other countries under its more direct influence, their training was accordingly seen as a part of their education. It also becomes apparent that since nearly all the foreigners in transit had received previous training at an advanced level, at the time they entered the research laboratory of the Faculty of Medicine, there is an indication that this was a requirement that applied to the élèves coming from abroad. In support of this point the case of Luguinin may be pointed out. When Luguinin, who had been trained as an army officer, left Russia for the first time and approached Wurtz to receive training, the latter considered that his preparation in chemistry, which had been acquired through attendance of lecture courses in Karlsruhe and Heidelberg was not enough. Thus, he was advised to go abroad and attend laboratory courses, which he did, in the Polytechnic School at Zurich. Only after this preparation, was Luguinin admitted to Wurtz's laboratory[49]. However, it seems that, in general, the requirement of possessing advanced laboratory skills was not subordinated to the possession of academic degrees or diplomas, if we take into account the cases of Lecoq de Boisbaudran, and that of Henninger[50]. In fact, it seems that the admission of both French and foreign élèves was based rather on an evaluation of their respective skills and potentialities than on diplomas.

6. Some social and cultural aspects of Wurtz's élèves and the choice of Wurtz as a maître.

The social and cultural features of Wurtz's élèves, which are to be presented next should not be seen as exclusive of his école. My aim is at the characterisation of the élèves as a whole and not to claim that their features were unique or even acquired at Wurtz's école. Obviously, their characteristics were part of the context of the time and they were shared by élèves of different nationalities. Consequently, Wurtz's école should be seen as a place where people sharing European rather then simply French cultural affinities gathered. Cultural affinities, which embodied also religious aspects seem to have been important. Although conclusions about the religious denominations or beliefs of the élèves cannot be drawn, especially due to lack of information, we may say (even leaving aside the Alsatians) that the majority of Wurtz's foreign élèves came from Protestant countries. This fact was surely relevant for the definition of the cultural context in which they were educated and brought up. Cultural similarities linked those of Alsatian origin, Germans, Austrians, Russians, and Dutch, who among other features shared the fact of having been educated in German type Gymnasia. But additonal conclusions may be drawn. Thus, from **Table VII** and also from the previous analysis of the backgrounds of the hard-nucleus, we may conclude that most of Wurtz's élèves came from wealthy families and for this reason they were allowed to choose without economic constraints a maître or maîtres who better conformed with their own views. Yet, if the élèves did not always belong to an economic elite, the great majority were part of a cultural group of European dimension presenting some homogeneity. Their education was generally broad and diversified by often allying science with music, literature and fine arts, being complemented by travel and contacts abroad, and favouring cosmopolitan personal and collective experiences. In general, their posture was not far from the prescriptions of Schelling, Schleiermacher, but especially from Fichte's ideas on the education of scholars[51]. Notably, Crafts traced back the recent origin of this tradition to the cosmopolitan savant, A. von Humboldt:

> Yet, this school [Wurtz's] succeeded in some measure to that of Liebig, and was visited by chemists of all nations; for European science still held to the traditions of Humboldt, and a sojourn, however short, at Paris was considered a desirable part of a scientific education.[52]

In accordance to this same tradition, Wurtz himself[53] like many of his élèves[54] both French and foreign assigned to imagination and intuition an important role in science[55] which, while contrasting with the current views of the French establishment, did not conflict with their image of science and of savant. Wurtz's élèves generally added to their scientific knowledge the knowledge of several languages, which facilitated communication and eventually collaboration within the international scene. This emphasis on communicating was also expressed in the range of publications produced throughout their lives. These covered a wide variety of subjects ranging from history of science[56], collective publications like dictionaries of chemistry and catalogues,[57] and sometimes mutual translations of books and articles on chemistry[58].

Their taste for travelling, which was not always confined to scientific interests and included countries with a Romantic aura such as Italy and Scotland, together with the visits and attendance at foreign laboratories are striking and seem to have been framed in the idea of self-cultivation. This was carried out through the establishment of various and widespread contacts in order to find a personal direction in a scientific profession. As Markovnikov said about his maître Butlerov:

> He did not have to finish his education, as did most of the Russians sent abroad. He had to see, rather, how scientific experts work, to observe the origin of ideas and to enter into intimate relations with the ideas, which the scientists readily exchanged in personal conversations... those were often held privately and not committed to print... With a basic reserve of scientific knowledge and possessing absolute fluency in French and German, he had no difficulty in standing on equal footing with young European scientists, and owing to his outstanding abilities, choosing the correct direction.[59]

Indeed the idea of self-cultivation, which itself embodied the concept of individual free choice and independent thought, was apparently highly valued by these chemists still fond of the Romantic tradition. This independence was either manifested in relation to the scientific establishment, in general, or in relation to a blind and strict adherence to the principles advocated by the écoles they attended. In the first case, and especially among the French élèves of Wurtz, their views often challenged the scientific status quo, as for instance in the cases of Le Bel and Grimaux, but also among foreigners unorthodox attitudes may also be found. As regards the second case, the words of Wurtz's friend Kelulé (below) may well translate the situation. In fact later in his career Kekulé by quoting Goethe, was to summarise his own experience and indeed that of others like Wurtz, who had distanced himself from Dumas's and Liebig's ideas to create a personal orientation. This was, after all, the very essence of the concept of Bildung :

> May I establish a precept for my younger colleagues? Free yourself from the spirit of the school; you will be then capable of doing something of your own. Remember that it was Mephisto who gave Faust the advice:
>
> It is al/ways best
> to hearken to one voice alone
> and swear by the word of the master.[60]

As one of the striking examples of how all these cultural similarities were decisive, the case of Butlerov seems to be paradigmatic. Butlerov was educated in a Gymnasium in Kazan and when he came to Wurtz he had already been converted to Gerhardt's views by Zinin. He only spent about 2 months at Wurtz's laboratory but, while attending it, besides his engagement in chemical research he became actively involved in the foundation of the Société Chimique de France:

> Butlerov was to be until his departure from France one of the most encouraging, lively and assiduous participants of the Société...on 10 and 11 March he developed fully his concept about what the Société should be.[61]

In addition, he kept in touch with Wurtz throughout his life and remained closely attached to him as their correspondence revealed[62]. He created what is generally considered the first Russian école of chemistry in 1858 when he returned to Russia, and established a research laboratory in Kazan. This initiative was to receive Wurtz's blessing and encouragement:

> Allow me to congratulate you for your scientific activity. You are producing research and making others produce. You are gathering around you élèves and, in this way, you are doubling your

contribution to scientific progress.[63]

In 1868 he moved to St. Petersburg and re-established his école and, assuming a similar attitude to that of Wurtz regarding the admission of female students in the Faculty of Medicine, from 1878 onwards women were included[64] in the activity of his laboratory.

He was considered a real chef d'école and his élève Gustavson even compared him to Dumas's model of the ideal maître[65] denoting the influence of French culture. However, what was emphasised by Butlerov's élèves Gustavson and Alexeev[66] was his originality as a chemist, together with his open and collaborative posture which was parallel to that which Wurtz had adopted. This same attitude was to find correspondence also at the French side of Wurtz's école, notably in his successor Friedel[67]. However, besides these factors others had to be considered.

Apart from Richet who emerges rather like a collector of maîtres, a procedure which allowed him to distance himself[68] from, but, nevertheless, affirm a respectable ancestry, the motives which underlie the choice of Wurtz as a maître had also other explanations, which were especially important within the French context.

First the theoretical framework, which was to play an ambivalent role insofar as if its adoption was a requirement for those who carried out research in Wurtz's laboratory, it also motivated the élèves in the choice of his école as a place to receive training. As we have seen, the foreign élèves when they arrived at Wurtz's laboratory were generally already acquainted with Gerhardt's type theory and atomic theory. But in the case of the French élèves two situations occurred: either the élèves had previous contact with these principles as happened, for instance, with Lauth (since he had been Gerhardt's préparateur[69], and with Grimaux via Naquet[70], or for other reasons such as cultural, they chose Wurtz as maître and were trained accordingly afterwards. Indeed, the theoretical principles of chemistry adopted by Wurtz, as a part of the système he advocated were a central point for the majority French and foreigners to become one of his élèves.

His système, however, had other components, notably the activities in a wider context, in which many of his élèves were involved, and this could be, alone or together with research training, a reason to chose Wurtz as a maître. In fact, among the examples those of Etard and

Demarçay illustrate the situation. Both of them had been trained by Cahours, considered themselves his élèves and remained linked to this chemist all their lives. Yet, they also saw themselves as élèves of Wurtz, not only because they shared similar views regarding chemical theory, but because Wurtz's école gave them the opportunity of expanding their participation especially at the editorial level[71]. Indeed, under Cahours's direct auspices these kinds of activities were impossible due to the modest dimensions of his école. But these two cases also raise the question of patronage, since despite the admiration that they might have devoted to Wurtz, by considering themselves as his élèves, they were under the protection of a more powerful maître than Cahours. Thus, patronage was surely a strong factor in order to choose a maître as long as he had power within the national scene.

Wurtz's position in the French system, although not all-powerful, had some peculiarities which allowed him to have unique characteristics. On the one hand, his personal authority was linked to his professorship at the Faculty of Medicine and later with his deanship, which gained him recognition. Moreover, his école was well renowned and especially recognised abroad, making possible attacks within the French scene more difficult. Finally, he had the protection of Dumas at the administrative level, and Wurtz saw his power increased, when he was elected to the Académie des Sciences. If these were the conditions which transformed him into a part of the French establishment, enabling him to exert some control over it and exert patronage, his religious beliefs and cultural background allowed him, on the other hand, to have an independent posture. In this way he was able to protect those who could be easily marginalised by the establishment due to some sort of non-conformity as shown before. Besides the examples of non-conformity mentioned in the hard-nucleus, the case of Lecoq de Boisbaudran, shows even more clearly how non-conformity and patronage could be allied. Simultaneously, it also demonstrates how someone already with personal ideas on chemistry had to choose a maître in France.

Lecoq de Boisbaudran belonged to a ruined Protestant aristocratic family of Cognac. Owing to financial problems, his education had been elementary and as a chemist he was self-taught. Thus, in his background apart from religion there is not any other feature that he could share with Wurtz. To earn his living he was in the cognac business and carried out his research at an improvised and rudimentary laboratory in his house. As his investigations developed, his private laboratory could not meet their requirements and he came to Paris to try to continue his work. His first attempt was presumably with Deville[72], but his unconventional education and probably his unorthodox vision of science, inasmuch as he claimed to enjoy his "theoretical dreams"[73], prevented that chef d'école from trusting him with the expensive reagents involved in the study of rare earths. He then went to Wurtz and was accepted by him, who together with Friedel encouraged his work, and in this way Boisbaudran discovered gallium (1875). In fact, by receiving Wurtz's hospitality, encouragement and, above all, protection he was able to have his investigations accepted and recognised, since it was Wurtz who was behind the presentation of Boisbaudran's work to the Académie des Sciences[74]. But not all the élèves were in such a situation and therefore Wurtz's patronage was exerted differently. Due to lack of information Wurtz's direct role as a patron can be inferred from a few examples, rather than fully documented.

As regards the French élèves who were more likely to be interested in official posts, it is plausible to think that in this situation the procedure consisted of a previous conversation between Wurtz and Dumas followed by a letter in which Wurtz reminded his former maître of the names of the élèves in question and of the possible posts[75]. This was accompanied by a letter from the candidate in which he described his scientific production at the same time as he asked Dumas for his "powerful protection"[76].

This procedure, however, could eventually extend the power of the école as a whole, since the coverage of the available posts in the various institutions was in this way ensured. This conquest of posts, nonetheless, was not apparently very effective due to the powerful positions of Deville and Berthelot especially in institutions for higher education. As Gautier mentioned, rivalry was a major ingredient at the time and the struggle for supremacy over universities or similar institutions was particularly acute:

> Side by side with the young elite that chose Wurtz for maître and patron two rival écoles almost conflicting, those of Deville and of Berthelot, for a long time disputed the power, the prominence in the instruction of young people at the official educational institutions in France.[77]

However, taking into consideration the strong power of the écoles of Deville and Berthelot, and the fact that the majority of Wurtz's élèves were foreigners, who were not interested in academic posts in France but in returning to their own countries after receiving their training, the role of Wurtz's école at this level was limited.

As regards the foreign élèves we can infer that Wurtz's role as patron might have been played in the form of letters of recommendation as had happened with him when he returned from Giessen. The case on which this hypothesis is based is that of Beilstein when he was to be elected to the Academy of Sciences of St. Petersburg[78]. Despite the availability of just this single case it is plausible to assume that Wurtz may have used his personal influence in a more or less systematic way whenever professional posts were involved in foreign institutions of higher education as well as when elections to Societies and Academies were likely to be influenced in their decisions by his opinion about candidates who had been his former élèves.

NOTES TO CHAPTER 3.

1- According to Friedel's testimony,

> Ce n'est pas la liste complète de ces élèves qu'il serait impossible de reconstituer aujourd'hui, les registres du laboratoire ayant étés détruits.

FRIEDEL, C., "Notice sur la vie et les travaux de Charles-Adolphe Wurtz", Bull.Soc.Chim.Fr., 43 (1885), 1-79 (22). See also HJELM-HANSEN, N., "Une lettre inédite de A. Wurtz à J.-B. Dumas", Rev. Hist.Sci., 13 (1860), 259-265 (259).

2- Bernard de Palissy was a French savant, writer and porcelain enameller born in 1510, who converted to Protestantism in 1543. He was victim of several religious persecutions and was killed probably in 1589 at the Bastille. The original statue by Barrias is located in the Quartier Latin.

3- See op.cit. (1), 22.

4- Letter sent to Dumas on 15 February 1864. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

5- GILLISPIE, C.C., (edit.), Dictionary of Scientific Biography, (New York, 1970-1980), 16 vols..

6- MAIRE, A., Catalogue des thèses de sciences soutenus en France de 1810 à 1890 inclusivement, (Paris, 1892).

7- PAQUOT, M.C., Mémorial de la Société Chimique de France. Histoire et développement de la Société Chimique depuis sa fondation, (Paris,1900).

8- PREVOST, A., La Faculté de Médecine de Paris, ses annexes et son personnel enseignant de 1794 à 1900, (Paris, 1900).

9- Catalogue of scientific papers compiled and published by the Royal Society of London, (London,1867-1918), 19 vols.

10- POGGENDORF, J.C., Biographisch - Literarisches Handwörterbuch, (Leipzig, 1863-).8 vols. in 4.

11- This formula was especially adopted after 1852 and may be found throughout the life of Wurtz's école.

12- As for instance Butlerov, who came to Wurtz for a short period and did not have to pay the fee as he explained:

> J'ai eu la possibilité de faire ces recherches auprès de A. Wurtz, qui m'a permis de travailler gratuitement dans son laboratoire de l'Ecole de Médecine. Ces recherches m'ont permis d'établir de fructueux contacts avec de nombreux chimistes

JACQUES, J.; BYKOV, G.V., "Deux pionniers de la chimie moderne, d'après une correspondance inédite", Rev.His. Sci., 13 (1960), 115-134 (116).

Thus, such an acknowledgement is not surprising:

> En terminant c'est pour moi un devoir d'exprimer ma reconaissance à M. Wurtz dans le laboratoire duquel ces recherches ont été entreprises et dont les conseils bienveillants m'ont guidé dans le cour de mon travail.

BUTLEROV, " Mémoire sur l'iodure de methylène", Ann.Chim., [3] 53 (1858), 313-321 (321).

13- To exemplify this situation we may mention the case of Friedel. In his first paper entitled " Note sur les constitutions des acétones", C.R., 45 (1857), 1013-1018 (1013), he mentioned Wurtz's laboratory as well as in his second " Sur la production des acétones mixtes", C.R., 47 (1858), 1165-1167, but from this time onwards often he does not mention it at all.

14- The case of Clève, a Swedish chemist collaborating in the Bulletin of the Société Chimique and in other initiatives, who carried out research in Wurtz's laboratory, but never mentioned it in his publications. See Table I (Appendix 1).

15- The élèves whose nationalities were uncertain were not taken into account in these calculations.

16-CRAFTS, "Friedel Memorial Lecture", Journ.Chem.Soc., 77 (1900), 993-1019 (995).

17- A remark should be made due to the fact that the élèves who published jointly with colleagues or with Wurtz, often published also alone.

18- See Chapter 2,

19- These foreign élèves were the Portuguese Agostinho Vicente Lourenço, whose thesis was entitled Recherches sur les composés polyatomiques (Paris, 1862), and the Swiss Adolphe Perrot, who resided in France over a long period see Table IV (Appendix 1).

20- See Chapter 1, section 3.

21- MAINDRON, E., Fondations de Prix à l'Académie des Sciences. Les lauréats de l'Académie, 1714-1880, (Paris, 1881) and GAUJA, P., Les Fondations de l'Académie des Sciences (1881-1915), (Paris, 1917).

22- See Chapter 1, section 2.2.

23- Besides Le Bel who had a long dispute with the Académie des Sciences, Scheurer-Kestner mentioned that:

> Mon charactère ne se prête à ce qui est demandé à un candidat. La brimade des visites imposée aux nouveaux par les anciens me révolte et me répugne. Je comprends les visites après l'élection; avant, c'est quelque peu humiliant pour un homme fier qui se sent quelque valeur.

He was also very critical about the Légion d'Honneur. See LAUTH, C., " Notice sur la vie et les travaux de Aug. Scheurer Kestner", Bull.Soc. Chim.Fr., 26 (1901), 1-31 (5).

24- Friedel in the introduction of Wurtz's posthumous book La théorie atomique, (Paris, 1888) emphasised Wurtz's role in terms of a heritage:

> Dans l'héritage d'un homme illustre, il n'est permis qu'à un petit nombre (s'il en est d'assez pour cela) de recueillir les dons éminents, le talent, l'éloquence, la supériorité de l'intelligence, l'esprit d'invention; mais ce qui est à la portée de tous, ce qui féconde les germes les plus divers de chacun, ce sont les qualités morales sans lesquelles il n'est pas de véritable grandeur.

25- URBAIN, G., "Jean-Baptiste Dumas (1800-1884) et Charles -Adolphe Wurtz (1817-1884), leur rôle dans l'histoire des théories atomiques et moléculaires", Bull. Soc. Chim. Fr., 1 (1934), 1425-1447 (1440).

26- No exhaustive investigation was carried out in order to have a deep knowledge about the third generation. These are just few examples.

27- The foreign élèves participating in the Karlsruhe meeting were Beilstein (Göttingen), C. Gundelach (Manheim), G.C. Foster (London), Lieben (Austria), Sawitsch (Kharkov), Schiff (Switzerland), Luna (Spain). The French were Gautier (Montpellier), Friedel (Paris), Scheurer-Kestner (Thann, Alsace).

28- He notably presided over the International congress of chemists held in 1892 in Geneva for the reform of chemical nomenclature. He was helped by two other Wurtz's former élèves, Beilstein and Butlerov.

29- Combes was to become deeply involved in these tasks after the International Exhibition of 1889.

30- HANRIOT, M., "Arthur Henninger", Rev.Sci., 34 (1884), 632-633 (633).

31 As Hanriot explained

> Il était le successeur désigné de son illustre maître et céda aux sollicitations de ses amis qui désiraient le voir prendre la direction de l'Ecole de Wurtz

HANRIOT, M., "Notice sur la vie et les travaux de Charles Friedel", Bull.Soc.Chim.Fr., 24 (1900), 1-51 (6)

32- As Crafts mentioned

> Both Alsatians, united by tastes, opinions, and pursuits, the elder chemist opened the way for the younger in professional and editorial work. Wurtz's high reputation, his activity in public affairs as well as in science led to the creation of the chair of organic chemistry at the Sorbonne, and after Wurtz's death in middle age, Friedel's studies and talents naturally marked him out as the successor.

Crafts, op.cit. (16), 997-998.

33- Evidence was found about Friedel's patronage of Silva in relation to a post in the Ecole Centrale des Arts et Manufactures. Letter from Friedel to Dumas written on 2 September 1882. Paris, Archives de l'Académie des Sciences, Dossier Friedel. Also Philippe de Clermont regularly used his many relationships in the scientific and industrial world to find posts for his élèves. MEUNIER, J. "Notice biographique sur Ph. de Clermont", Bull.Soc. Chim.Fr., 35 (1924), 809-816 (812).

34- See Chapter 5.

35- They contrasted with Deville's élèves, who being also attached to their maître throughout their lives, limited their research to his laboratory at the Ecole Normale. Thus and those who held posts at the Sorbonne, for instance, did not develop further écoles there. See Chapter 2, when Wurtz complained to Butlerov about the routine at the Sorbonne.

36- LAUTH, C., "Notices: Paul Schützenberger", in Agenda du Chimiste, (Paris, 1898), p.473.

37- CANNIZZARO, S., quotation on the cover of Centenaire de la naissance de Charles Friedel, (Paris, 1932).

38- LAUTH, C., "Notice sur la vie et les travaux de Aug. Scheurer-Kestner", Bull.Soc. Chim. Fr., 26 (1901), 1-31 (4).

39- HALLER, A., "Notice sur Charles Lauth", Bull.Soc. Chim.Fr., 21 (1917), 1-15 (12).

40- Especially Friedel, who in the several obituaries he composed such as those devoted to Silva, Combes, and Salet gave special emphasis to these features. Particularly in Salet's case he mentioned the criticisms addressed to Salet of spending too much time doing art which, together with his interests in intrument-making played a negative part when he attempted to be elected to the Académie des Sciences. FRIEDEL, C., "Notice sur la vie et les travaux de Georges Salet", Bull.Soc. Chim. Fr., 12 (1894), 17-32 (28).

41- As Crafts mentioned,

> "The second wife of Friedel cannot forget having passed her childhood near Nismes in a house where the coffins of her relations occupied one of the drawing rooms, because as Protestants they were refused Christian burial.

Crafts, op.cit. (16), 999.

42- Ibid.

43- VUCINICH, A., Science in Russian Culture, (London, 1965), p.220.

44- For each five readers of Kant there were 5000 readers of Schelling. Ibid., p.211.

45 Ibid.

46- See, for instance, Couper's education, who notably studied logic and metaphysics with Sir William Hamilton and moral philosophy with McDougal followed by several journeys abroad to study languages and science. ANSCHÜTZ, R., "Life and chemical work of Archibald Scott Couper", Proc.Roy.Soc. Edin., 29 (1909), 193-273.(197).

47 HELMHOLTZ, "La liberté académique dans les universités allemandes", Rev.Sci., 14 (1878), 813-820.

48- See GAUTIER, A., "Charles Adolphe Wurtz, sa vie, son oeuvre, sa personalité", Rev.Sci., 55 (1917), 769-789 (776).

49- GUILLAUME, C.E., "Wladimir Louguinine", Rev.Gén.Sci., 23 (1912), 1-3 (2).At the same time he attended Wurtz's laboratory he also attended Regnault's, but he soon left to return to Russia due to family problems. Only in 1881 did he return to Paris, becoming an élève of Berthelot and for ten years he engaged in thermochemical research.

50- Henninger entered Wurtz's laboratory when he was 17 years old, possessing only what was seen as a solid secondary education acquired in Nassau from where he and his family had escaped when his homeland was annexed by Prussia. It was while attending Wurtz's laboratory that he completed his education with a degree and a doctorate both in medicine. SCHUTZENBERGER, P. "Discours de M. le Professeur Schutzenberger, vice-président de la Société Chimique, prononcé aux obsèques de M. A. Henninger, le 10 Novembre 1884", Bull.Soc.Chim.Fr., 42 (1884), 547-549, and Hanriot, op.cit. (27).

51- See Introduction.

52- Crafts, op.cit. (16), 995.

53- See Chapter 2, section 3.

54- As van't Hoff, for instance, who was an admirer of Byron and inclined to poetry and music. He advocated the great importance of imagination in science, and blamed university studies because, in his opinion, they were too matter-of-fact, transforming people into "shrivelled scientific conglomerates"., WALKER,, J., "Van't Hoff Memorial Lecture", Journ.Chem.Soc., 103 (1903), 1127-1143. Although his relations with Le Bel had been extremely superficial while they both attended Wurtz's laboratory, and their independent discoveries about the asymmetry of carbon , we may point out a certain identity of attitudes, i.e.,they seem to have in common their almost total rejection of officialdom and academic praxis. See POPE, W.J., "Obituary notice. Joseph Achille Le Bel", Journ.Chem.Soc., (1930), 2789-2791.

55- Both Deville and Berthelot had opposite views as mentioned in Chapter 1.

56- For instance Bolton who, among other work published Priestley's scientific correspondence, and Ladenburg whose work had the recognition of the historian of science G. Sarton. See Article Bolton in JOHNSON, A., (edit.), Dictionary of American Biography, (N. York, 1957), vol.1, p.422-423.and SARTON, G., "Albert Ladenburg", Rev.Gen Sci., 22 (1911), 937-938 (938).

57- For instance Beilstein with his Handbuch der organische chemie which became popular among chemists as "the Beilstein". With this book he inaugurated a new kind of chemical literature consisting of organising systematically all the information concerning a large number of compounds, which were constantly synthesized and studied.

58 For instance Greene, who translated into English Wurtz's Leçons élémentaires de chimie and Alexeev, who translated into Russian Wurtz's Leçons de philosophie chimique.

59- MARKOVNIKOV, quoted from BYKOV, G., Article Butlerov, Op.cit.(5), vol.2, pp.620-625 (621).

60- Quoted from an English translation given by FISHER, N. "Kekulé and organic classification", Ambix, 21 (1974), 29-52 (33).

61- JACQUES, J., "Boutlerov, Couper et la Société Chimique de Paris", Bull.Soc.Chim.Fr., 20 (1953), 528-529 (529)

62- Bykov ; Jacques, op.cit. (12).

63 Ibid., 126

64 Notably the Russian chemist Julia Lermontova, a friend of the mathematician Sophia Kovalevsky, worked for some years in Butlerov's research laboratory. See footnote 18 in ALIC, M., Hypatia's heritage. A history of women in science from antiquity to the late nineteenth century, (London, 1986), p.207. Also FIGUIER,

"Alexandre Boutlerov", L'Ann.Sci.Ind., 30 (1886), 595-596 (596).

65- According to his comment:

> En comparant à Boutlerow cette belle image de maître idéal, on pourrait vraiment croire que le célèbre chimiste français [Dumas] avait l'intention de faire son portrait.

Gustavson, quoted from ALEXEYEFF, "Notice nécrologique sur A.-M. Boutlerow", Bull.Soc.Chim.Fr., 47 (1887), 1-10 (7).

66- Thus, he said :

> M. Boutlerow travallait toujours ouvertement , sous les yeux de tout le monde. Il faisait quelquefois les opérations les plus subtiles, exigeant une attention particulière, en présence de plusieurs personnes, souvent au milieu d'une conversation animée. On peut affirmer que même il pensait ouvertement, puisqu'il faisait part aux autres de toutes ses suppositions, et qu'il les vérifiait également devant les personnes qui l'entouraient. Il ne faisait point de secret ni de ses idées, ni des tentatives de les mettre à l'exécution. Ibid., 8.

67- According to Crafts's testimony,

> ...preferring to leave very ample opportunities to all those around him for doing original work and publishing it alone, whilst aiding them untiringly with his counsels. For these reasons, the volume of his contributions to chemical research is not very large and many an idea passed into others for execution

Crafts, op.cit. (16), 998.

68 As he mentioned:

> D'ailleurs, je dois avouer que ces grands maîtres, Wurtz, Berthelot, Marey, Claude Bernard et Vulpian ne m'ont influencé qu'indirectement; ils me laissaient généralement travailler seule.

Richet was a medical doctor who received the Nobel Prize in 1913 because of his discovery of anaphylaxy. He was probably able to attend the several maîtres without constraints due to the prestigious position of his father, a surgeon highly regarded in the Parisian scientific establishment.RICHET, C., "Autobiographie" Les biographies médicales (1930-1936), (1936), 157-188 (160).

69- Haller, op.cit., (34).

70 ADAM, P., "Notice sur la vie et les travaux d'Edouard Grimaux", Bull.Soc.Chim.Fr., 9 (1911),1-36 (3).

71- In fact, they integrated the editorial boards of the Bulletin de la Société Chimique on several occasions as well as collaborated in Wurtz's dictionary.

72 Although Urbain had not mentioned explicitly the name of Deville, he mentioned that the laboratory Boisbaudran went to first was very well equipped, better than that of Wurtz. Since Deville's laboratory was considered the best equipped in Paris and also given the nature of Boisbaudran's investigations, we may speculate that it was this laboratory. URBAIN, G., "L'oeuvre de Lecoq de Boisbaudran", Rev.Gen.Sci., 23 (1912), 657-664 (664).

73- According to his own words, at the end of his career:

> Me voyant empêché par diverses causes de continuer mes recherches et les rêves théoriques dans lesquels mon esprit se complaisait...

together with his assumptions about the existence of atoms, suggest the type of difficulties he may have found in order to be accepted by the French scientific community.
Quoted from GRAMONT, A., "Lecoq de Boisbaudran, son oeuvre, ses idées", Rev.Sci., 51 (1913), 97-109 (108).

74- Ibid.

75- See letter of 13 August 1875 sent by Wurtz to Dumas reminding him of the candidacy of his élèves Girard for the direction of the recently created laboratory of the Contributions immédiates, and also of Dupré, Wurtz's préparateur at the time, who wanted a post at the same laboratory. Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

76- See letters addressed to Dumas by Dupré and Girard on 13 August 1875 reporting on their respective research and publications. Dupré mentioned:

> L'accueil bienveillant que vous nous avez fait à M. Girard et à moi, nous fait espérer que votre puissante protection ne vous fera pas défaut.

Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

77- GAUTIER, A. "Le cinquantenaire de la Société Chimique de France", Rev.Sci., 7 (1907), 641-689 (688).

78- Beilstein disputed with Mendeleev a place in the Academy of St. Petersburg and asked Wurtz for a reference letter. Wurtz did not know that Mendeleev was involved, but after Butlerov has informed him he asked for his letter to be withdrawn, assuming a neutral position. Jacques; Bykov, op.cit. (12), 131-133.

CHAPTER 4- THE ECOLE: THE LABORATORY AND THE SYSTEME.

1- The laboratory, its peculiar administration, atmosphere and organisation.

As previously mentioned, with both Dumas's resignation from his professorship and the death of Orfila, their respective chairs were unified and Wurtz was promoted to Professor of chemistry at the Faculty of Medicine in 1853. With this new post he was allocated some rooms that he and his élèves gradually converted into a research laboratory. These premises were to remain the same until 1877, when the Faculty of Medicine was rebuilt, and the necessity of an appropriate research laboratory became officially recognised by the administration.

The conditions that Wurtz and his élèves found in 1853 were far from being satisfactory since the space which was to become their laboratory had been taken from the anatomy lecture theatre. It was lofty, with a vaulted roof, good daylight and besides Wurtz, it could accommodate about a dozen élèves[1]. The balances were placed on a small table in the adjoining lecture theatre and were not available whenever a lecture was in progress. Other adjoining rooms, which were initially used for special experiments on a large scale such as combustions, had afterwards to be given up for the ordinary work of the increasing number of élèves, who came to Wurtz's laboratory. A courtyard was also part of the facilities and played an important role when experiments considered potentially dangerous were carried out[2]. Nonetheless, and according to Friedel's words this research activity did not make great demands on the education budget[3].

Despite the fact that Wurtz's professorship had been created in 1853, the corresponding teaching and research laboratories were only given official accreditation in 1867[4]. This measure which included not only chemistry but all the experimental courses taught at the Faculty of Medicine, followed Wurtz's nomination as Dean of the Faculty in 1866 and was due to the internal policies that he launched[5]. In practical terms the lack of official recognition implied that no budget was given either for ordinary students to perform experiments or for staff and post-graduates to carry out research. In fact, only a small budget was available for demonstrations for the ordinary students of the Faculty, during the lectures. In addition, unlike his fellows chefs d'école, he was unable to appoint officially laboratory personnel who might have included his élèves for junior teaching posts. This situation, however, was not to lead to paralysis, since Wurtz overcame the limits of officialdom by adopting an independent solution, which valued private initiative. Thus, from 1853 he collected a fee from his élèves, which helped to pay for the infra-structure, laboratory equipment chemicals and other current expenses. For instance, as the rooms he was allocated were originally empty he had to connect gas and water supplies and to buy appropriate equipment . As Friedel commented,

> everything was done step by step, using the money paid by the élèves.[6]

Wurtz's attitude contrasted with those of his colleagues who depended entirely on funds coming from official channels and particularly with that of Pasteur. More tuned to the Catholic tradition whose relation to money is often ambiguous, Pasteur, despite the fact of obtaining large economic support from the Emperor and other official sources, presented himself as a disinterested savant with contempt for money questions[7].

But the exact procedures adopted by Wurtz were described by him in a letter to Dumas in 1864. In this letter, in which he expressed his ambition to be officially appointed director of the laboratory he had established, he reported on the different categories of élèves attending it, their corresponding fees, as well as on his own administration:

> 1. The beginners pay 100fr. per month; we supply them with everything.
> 2. Those who carry out research, and they are the majority, pay 50fr. per month. They are responsible for the raw materials required for their experiments and for expensive reagents such as bromine, ether, silver salts, platinum, etc.
> 3. Those who cannot afford to pay, if they have a great desire to carry out research, do not have to pay anything. I always have élèves, who fall in this category. With economic resources? Yes, with those I have been obtaining on my own in the last ten years and with which not only have I been able to face current expenses, but also those required by the installation of the laboratory. [8]

After mentioning some economic support that he received twice from the Deans of Faculty, Dubois and Rayer, for the construction of a fume cupboard with a chimney and a stone table in the courtyard, Wurtz added:

> Here it is all I received from the State. I also enclose a statement of the amount coming from private funds, which had been spent on the

> installation of the laboratory, between 1853 and 1862...For several years I have spending approximately 8000fr. per year . I devote 175fr. each month to compensate the préparateurs who both supervise the élèves and look after the laboratory. I improve the insufficient earnings of the garçon of the laboratory. I consider his work very important[9], because without order and neatness, everything goes wrong in a laboratory.

In order to reinforce and justify the whole of his initiative Wurtz provided a list of former élèves, mainly foreigners, who were already established in academic life in their countries of origin[10].

The procedures used by Wurtz in running his laboratory, were confirmed among others by Gautier, who mentioned that the amount paid monthly by the majority of the élèves was 50fr. when he arrived at the laboratory in 1863[11], which means that the majority were not beginners, but were chiefly doing personal research under Wurtz's guidance. Besides gas, reagents and personnel, money was also spent on books, since the laboratory built up its own small library, and on a private system of internal research grants. As Gautier mentioned, in order to encourage research quality whenever the research and publications of an élève were assessed nationally and internationally as particularly valuable, the fee was decreased or might even be cancelled.

For many years all attempts made by Wurtz to obtain a higher budget from the administration were unsuccessful, and when he pointed out the many contributions he claimed to have made together with his élèves, resulting from the use of these private funds,

> an eminent savant, whose influence was dominant[12], answered him: 'All I can do is to close my eyes to this irregular procedure.'[13]

As Léon Foucault had already pointed out in 1850[14] it seems that, at least until the mid 1860s, Dumas had been distracted from his former élève operating in the Faculty of Medicine. Dumas had directed his protection mainly towards his former élèves, politically more in tune with the policies of the Second Empire, whose research laboratories were located in the grandes écoles, and apparently he largely ignored what was going on at the Faculty of Medicine. Consequently, he did not commit himself to obtain funds from either the Academy or the Emperor to finance the research carried out by Wurtz's école as he had done in the cases of Deville and Pasteur, during the Second Empire. In fact, only in 1864, the year Wurtz reported to Dumas the details of both his personal research[15] and the situation of his école, after eleven years of "irregular" activity[16], did Dumas seem to have finally "opened his eyes". During its first decade Wurtz's école had developed outside Dumas's direct control and, at this point, its international prestige was already well established. His support, therefore, was to benefit both sides[17]: on the one hand, by associating his name with Wurtz's école his public image was favoured[18]; on the other, the life of the école was ensured due to his protection, despite the "illegal" procedures. From this moment onwards Dumas's support was constant, but rather institutional than financial, which helped Wurtz to maintain a more independent position regarding both the political regime and central administration, than that of his colleagues.

The way in which the laboratory was funded also had internal implications. As mentioned in the previous chapter, for the élèves the payment of the fee meant that they considered their training as a part of their education and, in addition, this ensured them more personal freedom and independence. Thus, there are no references to the engagement of élèves in laboratory work of "general interest"[19] as in the case of Berthelot, or to research designed by the maître, whose purposes were not understood by the disciples as occurred with Pasteur. In fact, the number of papers published by Wurtz's élèves under their own names corroborates the absence of these practices, excluding the possibility that his élèves might have been used as a highly qualified work-force for Wurtz's own profit. Furthermore, if his acknowledgements to those involved are considered[20], it seems that he was rarely assisted by his élèves in his own experiments. According to the testimonies available, he was portrayed in the laboratory in a rather different way from his colleagues:

> Without assuming the posture of a dogmatic professor or that of an assertive maître, he [Wurtz] listened to us attentively and modestly raised his questions or manifested his objections. He simply behaved as a more knowledgeable comrade, who advised his younger colleagues and was ready to accept their views and learn from them.[21]

This capacity of learning from others resulted in many references to the experiments of his élèves expressed in his papers and books, on which he built up subsequent experiments and theoretical generalisations[22]. From the evidence available, another material manifestation of the more egalitarian relationship existing between him and his associates was the fact that Wurtz's bench was no larger than the others offered to his élèves and he did not establish for himself spatial privileges inside the laboratory[23].

The routine of the laboratory presents, in addition, some peculiarities, which distinguished it from those of Wurtz's colleagues, distancing it from the image of a place of endless, continuous hard work. The laboratory opened at 10 in the morning and closed at 5 in the afternoon, but whenever experiments could not be interrupted the élèves were free to stay for the time they needed. In between small groups of élèves left the laboratory in turn to have lunch in neighbouring restaurants, where they interacted with other intellectuals including physicists, musicians, painters, philosophers, theologians etc.[24]. The relatively small number of working hours is associated both with Wurtz's ideology and the nature of the research programme. Unlike Berthelot, Wurtz's advocated a principle of simplicity and economy in science, which dispensed with the collection of huge amounts of data as in Berthelot's cumulative vision. In addition, the adoption of Gerhardt's table of types as the basis of a research programme allowed predictability and consequently worked out as as a time saver since it generally provided an effective guide for the generalisation of methods of preparation of new compounds and allowed Wurtz and his élèves to derive subsequent theoretical conclusions[25].

Wurtz's arrival at the laboratory every morning is described as very active. His first task was to remind or ask the garçon for apparatus and reagents required for experiments he had in mind. After putting in motion his personal investigations he went to each of the élèves ,

> to enquire not only on the state of our experiments, but especially on the state of our ideas.[26]

Life in Wurtz's laboratory combined in its practices the cultivation of features relating to the Romantic model of scholar's apprenticeship of notably Schelling and Fichte[27], i.e., the value ascribed to the individual as a creative person and, simultaneously, cosmopolitanism and the sense of belonging to a community:

> We lived there in a community of ideas, which we shared among us with the patron as we used to call him. We easily discussed the theories of the day and often quite intensively, particularly those of Deville, Pasteur, but especially Berthelot and foreign chemists. Each of us expressed his views or objections, listening to the opinion of

Wurtz, whose conclusions were not always accepted.[28]

These discussions were not restricted to scientific matters and as Gautier mentioned:

> We used to discuss not only Wurtz's chemical theories, but also his philosophical, religious and political ideas.[29]

The routine of the laboratory was far from that of a "sacred" place as held by Pasteur[30], and clearly challenged current patterns and values. Pasteur, himself manifested his astonishment and once when he went to visit Wurtz at his laboratory he found him among his <u>élèves</u> in an extremely busy room, and asked:

> - How can you work in the midst of such agitation?
> - It excites my ideas - answered Wurtz
> - It would put mine to flight - retorted Pasteur.[31]

The image of Wurtz's laboratory defied in other respects the limits of respectability currently ascribed to scientific activity at the time. According to several testimonies of his closest <u>élèves</u> it was common to hear Wurtz making humorous comments, and maintaining musical dialogues with some of his <u>élèves</u>, especially when the experiments were producing the results expected[32]:

> Under the resonant vaulted roof of the laboratory Wurtz's singing was often responded to by that of the young beginner Salet.[33]

Salet himself was to give a touch of satirical phantasy to the atmosphere of the laboratory, when he built up a sculpture with bottles and laboratory cloths representing Theory, with a serious and gloomy face, and Practice with a happy one, with which he decorated the wall of the large chimney.

In this laboratory where the outside world seems to have permeated often and easily through the discussions of ideas and events and where several nationalities gathered, the community of Alsatians seems also to have affirmed its identity in its own way. Although there is no evidence that they ever had special privileges inside the laboratory, they used to speak in their informal conversations their regional <u>patois</u>, of which Wurtz is said to have been fond. In addition, in war time, as during the Franco-Prussian conflict, the laboratory was used as one of the main meeting points in Paris, where Alsatian <u>élèves</u> and non <u>élèves</u> met regularly, since the community of intellectuals and influential Alsatian refugees considered it as "a portion of their lost homeland" [34].

Wurtz's laboratory at the Faculty of Medicine remained the same till 1877 and there is no evidence that there were great changes in its organisation. Nevertheless, with Wurtz's election to the post of Dean (1866) and his two reports on foreign laboratories[35] and on the state of the buildings of the Faculty of Medicine[36] subsequent reforms on research and teaching laboratories were carried out in this institution. As a result he was able to give his élève Gautier in 1874 a laboratory devoted to biological chemistry, which added to the activities of his école. This laboratory was available for use by the clinical Professors in the Paris hospitals[37], but its main purpose was the research carried out by élèves under Gautier's supervision. This integrated the already mentioned process of "decentralisation" and was associated with the acquisition of space, a process whose origin may be traced back to 1866, when Friedel as Curator of the mineralogical collection at the Ecole des Mines was allocated a laboratory.

In 1877 when the work of rebuilding the Faculty of Medicine began, as well as the process of official recognition of research laboratories[38], Wurtz's laboratory was provisionally transferred to an old building in the Rue Hautefeuille. This laboratory was, according to the sources, larger and more functional and, for the first time, Wurtz had a personal study. It was in these new premises that he carried out his last investigations surrounded by an even greater number of élèves and by what was described as his phalange de fidèles[39]. In this laboratory another innovation was introduced, denoting a more institutionalised form of organisation. Thus, instead of the informal discussions on current research in front of the blackboard, which regularly took place in the old laboratory, Wurtz was now organising seminars every Saturday afternoon, following the German practice. In these seminars, the topics of discussion varied, ranging from current investigation of Wurtz's élèves to chemical or non-chemical research[40] of other savants, both French and foreigners. Meanwhile in 1874 when Wurtz was appointed to the new chair of organic chemistry at the Sorbonne, as mentioned before, he had no laboratory facilities at his disposal[41]. Only in 1881, after Deville's death, was a laboratory given to him but merely for his lectures. He was expecting, however, that a kind of institute of chemistry[42] similar to the Germans and attached to the new buildings of the Sorbonne in the Avenue de l'Observatoire, was built. He collaborated in drawing up the plans of this institute with the architect Nénot, making use of his knowledge of foreign laboratories.

The kind of institute he was aiming at the Sorbonne was consistent with his views on the organisation of research that he expressed in his report on foreign laboratories (1878)[43]. Unlike Berthelot[44], he defended separate institutes of the German type[45], which to some extent were independent in physical and economic terms from the universities and, as he claimed, more able to compete with independent teaching[46]. Again his readiness to advocate solutions based on free and independent initiative, leading to a more competitive system, which was decentralised and independent from the State, suggests the influence of both his Protestant background as well as that of the German model. In logistic terms, his views on the institutes were based on the principle that the laboratories should be established in appropriate buildings, especially built according to what he considered modern scientific requirements and necessities. Wurtz argued that the old installations of the traditional universities and faculties could not meet those requirements, and criticized the French common procedure of using any available building to set up laboratories. Another aspect he criticized was the dichotomy existing in France between research and teaching laboratories which had been eliminated in the German institutes. He was thus advocating one of the central aspects of the Romantic model of university which prescribed that research should be itself part of normal university teaching and not confined to a special training after an university degree.

Regarding laboratories and research organisation, whose implementation Wurtz considered a "work of civilisation"[47], his position resulted from his critical balance of the past but also of the situation of his time. He saw science as a collaborative enterprise and, by comparing it with art, he claimed that:

> science is no longer the work of individuals it is a communal activity...a laboratory is not only a home for science, it is an école.[48]

However, his views on institutes for research were different from those more inclined to scientific triumphalism and he notably expressed his criticism regarding manifestations of fetishism patent in excessively ornamented laboratory buildings[49]:

> A defect we should avoid is the one I found in many laboratories I visited. Some buildings have a very monumental look and the luxurious decorations are exaggerated not only in façades but also indoors. Luxury is not appropriate here and simplicity, which does

> not exclude either the sense for right proportions or good taste, is more appropriate to the dignity and to requirements of science.[50]

2. The Système.

Neither the ideas of Wurtz on chemical theory nor his chemical investigations have ever been fully studied by historians, nor have there been studies in depth of particular aspects of his chemical thought, such as those we can find devoted to chemists such as Dumas[51], Laurent and Gerhardt[52] or Kekulé[53]. The available analysis of his work is practically reduced to references en passant in the course of historical analysis either on the contributions of his contemporaries or on the issues they tackled. As regards chemical theory, however,this situation may be explained by Wurtz's somewhat intermediate position between Gerhardt and Kekulé. In fact, Wurtz's views were located between an empirically based system of classification of compounds, in which these were seen from a functional perspective (Gerhardt)[54] and another, which although derived from the former, considered chemical species both in terms of chemical function but increasingly focussed on their constituent radicals (Kekulé)[55]. In addition, through the introduction of the concept of atomicity as a specific and constant property of atoms, Kekulé's system was to lead later to a structural description of compounds, which for some years Wurtz thought lay beyond the possibilities of chemists.

As the French heir of Gerhardt's system, Wurtz was to adopt a very cautious position in this whole process, giving the impression that he was unable to push the implications of his own conclusions further. Kekulé, who held him in a great esteem and shared many élèves, commented:

> I must repeatedly emphasize that in no way do I consider a large portion of these views as original to me, but rather I am of the opinion that in addition to the earlier named chemists (Williamson, Odling, Gerhardt), from whom more detailed observations on these topics are at hand, still others share, at least, the fundamental ideas of these views; above all Wurtz, who, never feeling it necessary to develop his ideas more fully, nevertheless permitted others of us to read them between the lines of each of his classic researches, through which the development of these views first became possible.[56]

Although Wurtz had played his role more at an European level, one should also take into account that, as a part of the French academic establishment, he was in a peculiar situation, since his most direct and powerful competitors, Deville and Berthelot and their respective écoles adopted theoretical positions, which were completely opposed to his and often accused him of an exaggerated concern with chemical theory and of relying too much on hypotheses. Notably, they were against atoms, and as a principle not only they denied their existence, but also refused their value as an heuristic tool. Adding to them Dumas, who having accepted atoms at least as an hypothesis until the 1840s, was to abandon his former ideas[57]. As we shall see in due course, and despite Dumas's apparent neutrality, the controversy on atoms and equivalents, which took place in the Académie des Sciences as late as 1877 gives us an idea of how hostile Wurtz's environment was, which to some extent may explain his excessive caution, if we take into account Kekulé's comment. But whatever influence this environment might have played on the formulation of Wurtz's chemical système it is worth analysing his personal version of Gerhardt's classificatory system and associated theories as well as the context in which it was established.

2.1.- Organic chemistry.

2.1.1- The three models.

In the mid-19th century chemists may be generally divided into two broad groups: those who believed that the main aim of chemistry was to reveal the real composition of organic and inorganic compounds and those who believed that classification was the greatest priority of their science. Among the first group we may point out the names of Berzelius, the European leading authority of the theory known as electrochemical dualism, and of his followers; among the second those of Laurent, Gerhardt, Wurtz and Kekulé, who provided a system of classification based on a theory known as type theory from which Kekulé was to derive his system of structural formulae. Both groups, however aimed at bringing mineral and organic chemistry under the same rules.

It has been pointed out by historians of chemistry that Kolbe in 1881[58] accused Laurent and Gerhardt of having pursued a sterile approach based on "phantasy-paintings" and of deriving "pencil and paper laws of nature" which contradicted "the true scientific method". Moreover he added that :

> The classificatory type theory of Gerhardt and Kekulé was succeeded by the paper chemistry which is called structural chemistry, which was based on results and ideas discovered by myself and my pupils, and which many young chemists pursue thinking that they are gaining insights into the spatial arrangement of atoms as they draw their drawings and paint their pictures. But in fact they have brought chemistry not a step forward by these means; rather, this is a reversion to the old Naturphilosophie.[59]

But the reasons why Kolbe associated the chemistry of his adversaries with Naturphilosophie . seem not to have deserved much attention, from historians. However, the presence of vocabulary and metaphors such as "type", "function", "metamorphosis", "protogénide", "scale", "place in scale", "unique plan", "rapports de parenté", "équation génératrice", "genetic relation", "chimie comparé" that we find in the writings of those who were accused by Kolbe is too striking to be ignored. If we accept that language is itself a factual evidence we may say that all these expressions were associated with an organic model of universe which had been especially developed from the views of the Naturphilosophen.

In fact the very names of mineral and organic chemistry in which chemistry was divided in the 19th century are revealing. During the 18th century compounds were referred to their natural sources and thus chemistry was divided into mineral chemistry, animal chemistry and vegetable chemistry according to the three kingdoms of nature. But, with the emergence of the concept of organisation[60] as, for instance, Lamarck[61] formulated it as early as 1778, a fundamental change was introduced, and nature became divided into two instead of three domains:

> one will first remark a large number of bodies composed of raw dead material, which increases by the juxtaposition of the substances forming it and not because of any internal principle of development. These beings are generally called inorganic or mineral beings...Other beings are provided with organs appropriate for different functions and are blessed with a very marked vital principle and the faculty of reproducing their like. They are comprised in the general denomination of organic beings.[62]

Therefore, since the vegetable and the animal were united under the organic, as a result chemistry became divided into only two branches, mineral chemistry[63] and organic chemistry, according to the distinct origin of its respective compounds[64]. As regards organic chemistry, only when compounds were dissociated from their natural origin and became described in terms of their structure, a definition of organic chemistry such as that of carbon-based compounds became possible. But the notion of organisation was also to lead to the emergence of a new science, when almost simultaneously Lamarck, Oken and Treviranus identified organisation with the living leading to a new science, which the latter coined under the designation of Biologie in 1802. Chemistry and particularly organic chemistry was to become closely linked to biological and organic concepts, which had been introduced in natural history, by using metaphors and models as devices for explanation, description and classification of compounds. Notably Comte was to consider organic chemistry as a branch of biology[65].

If we also accept that the "history of thought is the history of its models"[66] than we may say that the chemical thought in the 19th century, was based on three fundamental models that I would call: the mineral model, the physical model and the organic model.

1) The mineral model was associated with mineralogy, in its classification of minerals on the basis of their chemical composition. In terms of chemistry, it was well rooted in Lavoisier's substantialist tradition, which conceived compounds as binary combinations of elements. With Lavoisier's operational concept of element and later with the notion of equivalent, the composition of chemical substances had been brought to the realm of the visible and the measurable. Thus, as in natural history, in the 18th century classification in chemistry depended on direct evidence of the senses, i.e., on the elementary composition of substances in the terms put forward by Lavoisier. In the 19th century this approach, through the addition of an internal dimension, was supported by electrochemical considerations, especially due to Berzelius and some of his followers like Kolbe, Frankland, and in France these views were also to be incorporated in Deville's and Berthelot's chemical thought. Following the patterns of the mineral world and particularly the paradigmatic case of the formation of salts in mineral chemistry, they assumed that organic compounds were analogically obtained through an addition or (linear) juxtaposition of two elements or radicals, i.e., blocks of elements taken as

quasi-elements, with opposed electrical charges (electrochemical dualism). Their approach, being substantialist, did not emphasise classification and rather focussed on the qualitative and quantitative elementary composition. Consequently they emphasised the constituent chemical elements, rather than atoms. But, while the dualistic interpretation worked satisfactorily for mineral compounds, whose composition embodied a wide variety of elements, its explanations were challenged by the complexity of organic compounds, whose constituent elements were limited to a small range, basically carbon, hydrogen, oxygen and nitrogen. Since the concern of dualists was merely to determine the composition in terms of the proportions of the constituent elements in the radicals, without any further positional or functional specification, several problems arose. Particularly, this theory was unable to account for the differences between compounds with similar composition[67], but different chemical properties and behaviour, because it often represented the same compound by several different formulae and different compounds by similar formulae[68]. On the whole, this theory lacked of a consistent and responsive pattern of nomenclature and classification of organic compounds, which was not after all its main goal. Consequently, the attempts to subordinate the organic to the mineral within chemistry were to be highly debatable throughout the 19th century, although the most lively debates may be located in the first half. Among the participants in these debates were Liebig and Dumas as the leading figures, but also Laurent and Gerhardt. Liebig and Dumas, however, both portray the role of decisive figures in the transition from the mineral to the organic model.

2) The physical model encapsulated the mineral model, but was an attempt to unite mineral and organic chemistry under laws similar to those of (macroscopic) physics and was particularly associated with positivistic ideology. In France the main advocates of the physical model were Deville and Berthelot. Highly consistent with positivistic ideology, Berthelot particularly did not aim at explaining chemical phenomena through actual physical laws, but he tried to provide chemistry with a framework like that of physics in its macroscopic mechanical ("positive") sense , which was consistent with his reading of the hierarchical classification of sciences put forward by Auguste Comte. Berthelot was to incorporate electrochemical dualism and he rejected atoms, adopting a substantialist approach. He obviously advocated the extreme defence

of equivalents, which had been so acclaimed by Comte[69], since they allowed an approach to chemical compounds at a macroscopic level, i.e., at the level of the observable and measurable. As regards the interpretation of chemical reactions, since he claimed to reject hypotheses and theories not immediately derived from direct observation, he was led to develop thermochemistry, since it allowed him to derive laws from macroscopically observable and measurable physical parameters.

3) The organic model was closely associated with the vision of an organic nature put forward notably by the Naturphilosophen and aimed at the union of both mineral and organic chemistry under the rules of organic chemistry. The basis of the organic model in chemistry is related to the emergence of the concepts of organism and organisation, which occurred in the late 18th and early 19th centuries in natural history, and particularly within its empirical branch, comparative anatomy. In the late 18th century, empirical approaches to living bodies changed and the main goal instead of being a classification based on the analysis of their external features, became the analysis of their internal characteristics. In addition, in the early 19th century this analysis and comparison rather than operating only at the level of the internal components became gradually concerned also with the relationships between these components. According to Jacob[70], living bodies as scientific objects became three-dimensional entities in which the structures were arranged in depth and through the concept of organisation organs and functions were interrelated. As Lamark[71] pointed out, structural differences and functional constancy could be displayed and coordinated in the same frame. Thus, in the organic world, the very nature of empirical knowledge changed, and both German Naturphilosophen such as Goethe and Oken through transcendental anatomy and French anatomists such as Etienne Geoffroy de Saint-Hilaire, despite their differences, presented parallel ideas. Goethe, for instance, argued that plant organs were all metamorphoses of a primitive leaf. But the very notion of metamorphosis or transformation, presupposing a dynamic process introduced a temporal dimension. However the implicit notion of time in the early 19th century was not that of an active agent of transformation, but rather that of a time as scenario of change. In addition, in order to perceive an organism, Goethe claimed that

> the mind must embrace the whole and by abstraction deduce general

types from it.[72]

But others like Oken, whom Wurtz was so fond of, brought in similar views. Through his theory of the ideal vertebrate archetype, he advocated that an association of a single vertebra taken as the basic unit of a sequence would form the primitive model for vertebrates (Urtyp)[73]. Also in France similar ideas were advocated by Etienne Geoffroy de Saint-Hilaire, despite his philosophical approach, which was closer to Enlightenment materialism than to German Naturphilosophie[74]. Saint-Hilaire, in a parallel way to that which was to be adopted by Laurent, transferred from crystallography to comparative anatomy Haüy's notion of a "molécule intégrante"[75], which had provided a three-dimensional description of crystals. That notion together with the introduction of the concept of homology, led Saint-Hilaire to claim that homologous parts are anatomical elements of different species and are similarly related to the ideal plan even if they present different forms or carry out different functions[76].

However, a tension between structure and function was intrinsic to this new organic approach to the world due to the implicit presence of time, and several controversies arose as resulting from a different emphasis on the one rather than on the other, as for instance, that which took place between Saint-Hilaire and Cuvier. As Jameson pointed out, this tension was to be inherent in the organic model:

> Such was indeed the history of the organic model, that concept of the organism as a prototype with which a single spark touched off the Romantic philosophy and nineteenth century scientific thinking. The advantage of the notion of organism was that in it the realms of the diachronic and the synchronic found a living synthesis, or rather had not yet been separated, for it is the diachronic (the observation of gradual changes in the organism) which leads the attention of the observer to the synchronic structure (those organs which have changed and evolved and which are now to be understood in their simultaneous coexistence with each other in the life of the organism itself). Such notions as function are thus to be found at the very intersection between the two dimensions.[77]

In chemistry we found a parallel situation. Indeed organic compounds acquired in the 19th century a third dimension in depth and became to be seen as units whose description was "organic" in the sense that compounds were envisaged as a whole in which the parts had inherent relations among themselves and were in relation to the whole as if they were an organism. Moreover, tensions between structure and function became a crucial point in a science whose aim was classification for those who emerged as aligned with the organic model.

For Dumas the importance for any science of a classificatory system had been fostered by the Swiss naturalist Alphonse de Candolle, while in his youth he studied in Geneva, and it was natural history in its organic version which gave him the taxonomic general principles that his classificatory enterprise required[78]. Dumas, also aimed at unifying chemistry by subordinating the mineral to the organic, and in his system of classification[79] he made use of the idea of types which he transposed from comparative anatomy to his chimie comparée[80]. This resulted in his rejection of electrochemical dualism in c.1840. From the chemical point of view the system of classification was based on his aetherin theory, which his substitution theory. The organizing principles were that: an alcohol was a double hydrate of aetherin (ethylene) and an acid a single hydrate of the same radical; esters were formed from an anhydrous acid and ether and that aetherin is similar to ammonia, since with acids they both produce compounds with analogous composition. He established two series which allowed chemical classification through analogy. Moreover, with these principles, he was also able to explain reactions such as that between ethyl alcohol with chlorine producing chloral through a reaction of substitution. This kind of interpretation, which Dumas saw as a confirmation of his aetherin theory, was to become unacceptable for Berzelius and his followers, but was to be transformed by Laurent into a central question.

On the other hand, Liebig with his radical theory provided a slightly different interpretation from that of Dumas, and established his system of classification on the basis of two series, the ethyl series in which compounds contained the ethyl radical, and the ammonia series based on the radical ammonium. Liebig's theory was not in contradiction with electrochemical dualism, but unlike the latter he admitted that transformations could occur in the radical; however he did not develop his theory in order to explain substitutions. Nevertheless, Dumas's theories in particular led to a proliferation of substituted radicals that in their turn could undergo dualistic addition, and this was ultimately to cause enormous classificatory difficulties, which encouraged Laurent to develop another approach.

Laurent was a former élève of Dumas,who also had received training in crystallography from Biot. Laurent rejected electrochemical dualism and devised an approach to chemical compounds[81], which far from being empiricist was rather based on conceptual model building. As he denied that the arrangements of atoms in a compound could ever be derived from chemical reactions, he was to put forward a model, whose aims were the explanation of reactions and above all the establishment of criteria for classification .

In his model, Laurent approached the complexity of organic compounds through similar reasoning to that of crystallography. In particular, he transferred Haüy's concept of molécule intégrante, a device which allowed him to ascribe a third dimension to compounds, and analogically he developed his theory of the fundamental and derived radicals, which he called nuclei ("noyaux"), to distinguish them from the radicals of his predecessors. Indeed Laurent's radicals were conceived as three dimensional structures in which the positions of atoms were more relevant than their quality, since what he emphasised was the prevalence of the structure itself. These structures could undergo either substitution or addition and subtraction. The substitutions might or might not produce alterations of form, i.e., the product could be either isomorphous or possessing a different but derived form, but the additions would occur outside the radical, without structural disruption. The compounds were seen as wholistic material structures in which the components maintained their primitive composition (an acid and an alcohol existed as such in an ester), but whose primitive form might have been modified in order to preserve symmetry, for the sake of the stability and geometrical regularity of the whole structure as a unit. This three dimensional model together with his "principle of mutual generation", i. e., that compounds mutually convertible should belong to the same class, were to constitute the theoretical foundation of Laurent's classificatory system. However, the lack of technical instrumentation required to verify the structures, on the one hand, and on the other, the insufficient knowledge of reversible reactions led Laurent to introduce practical criteria. Thus, he assumed that compounds which can be converted into the same product without loss of carbon all belong to the same series. The system of classification he was to devise, was to be intersected by principles of classification inherent to the organic world. In the classificatory table[82] he put forward the several fundamental nuclei ("noyaux") as well as some derived nuclei ("protogénides"), both defining the genera, were displayed horizontally. Vertically he displayed the species, which were divided into groups according to the number of atoms outside the nuclei, and these were responsible for the immediate properties of compounds.

Implicit in Laurent's system of classification was a dualistic system of formulation, which he assumed in a relative sense. His dualism did not suppose a real division within a compound. In the later years of his short life Laurent was to claim that his synoptic formulae did not aim at representing the real arrangement of the atoms, therefore they were not absolute, and his three dimensional structures were seen as an heuristic tool, a guiding principle, which allowed him to reveal the possible connections existing between compounds and their chemical properties. On the whole the purpose of his system was classificatory but also explanatory, since it enabled the classification of compounds through the establishment of material analogies[83], and it aimed at the explanation of the reactions themselves. Laurent was to interact with Gerhardt while the latter developed his more empirically based organic model, but in its essence his project was abandoned with the premature death of his author.

Above all Gerhardt 's main goal was also to formulate a system of classification[84] which was to bring order to the vast amount of organic compounds, constantly emerging. The necessity of such a system if it was dictated by an intrinsic necessity of order within science, was also imposed by the particular status and role of the textbook, which was supposed to be a systematic presentation of chemical knowledge. Thus, for Gerhardt the textbook was simultaneously a means of diagnosis of the state of science and a constraint on its organisation, since it implied a passage from implicit to explicit knowledge on a topological basis[85]. As he stressed:

> The number of substances which occupy isolated positions in textbooks of chemistry and exhibit no family relationship is extremely large and is growing daily, to the detriment of science.[86]

The aim was to find a general organizing principle which allowed chemists to find links and relationships between chemical compounds, i.e., a pattern for their classification. As mentioned before, in its establishment Gerhardt was to denote the presence of the organic model, which in various ways permeated the 19th century thinking[87] as a foundation of organising procedures and classificatory systems.

The "great chain of being"[88] was to inspire Gerhardt's classificatory enterprise, ensuring continuity from the simplest to the most complex organic compounds through successive gradations in a process of growing complexification. Despite the presence of an implicit idea of evolution, this was not an evolutionary theory for chemical compounds since time as an active agent of transformation was absent. It was rather to some extent parallel to the idea of a "unique plan" as that advocated by the German Naturphilosoph Oken or by Etienne Geoffroy Saint-Hilaire in its French version of transcendental anatomy. In both as in Gerhardt, time had the passive role of background. As Gerhardt claimed ,

> If all organic substances are considered from this viewpoint, it can be seen that they show successive and practically imperceptible gradations, so as to form an immense scale, whose upper extreme is occupied by brain matter and other more complex substances, while at the lower end we find carbonic acid, water and ammonia, just above which come formic acid, wood spirit, and their derivatives. There is an infinite number of steps between these extremes.[89]

and as he was to add later,

> When chemistry has attained its highest degree of perfection, the substances of organic chemistry will constitute an immense system composed of a single series, beginning with brain - matter and ending with water, carbon dioxide and ammonia.[90]

Despite his adoption of this model to frame his system of classification, in order to make this large project work Gerhardt had obviously to introduce practical procedures related to chemistry. But if he brought in the categories from the organic world, he confined himself to chemical criteria to derive and confirm his assumptions. Thus, to make it feasible Gerhardt began by concentrating on the simplest compounds of the scale, which led him in c.1842 to reform equivalent weights and to operate on the basis of Dumas's substitution theory, establishing in this way a system of conventions which included his concept of homologous series[91]. This system, which in his opinion was consistent with a basic requirement of simplicity and economy, was ultimately to provide a tool for any "chemist however limited his skill"[92] to locate any compound in a given place in a classification chart. In order to achieve his goal, he was to incorporate in his theory further refinements[93] and this project in itself was to reveal the necessary potential to become a scientific programme to be explored.

Associated with his classificatory scheme Gerhardt introduced his unitary view (chemical unitarism), in which a molecule was regarded as a unique system formed by an aggregate of atoms in a particular but unknown order. These atoms could be of the same kind in a simple body or of different kinds in a compound[94]. His system of formulation was empirically derived and systematised in his theory of types, which presupposed that compounds undergo only reactions of substitution and double decomposition. Typical formulae did not aim at representing the arrangement of the atoms in a compound, which he believed was impossible to be derived from an empirical basis and, unlike Laurent, indeed unattainable by a purely rational approach or by any other means. They were rather the application of his méthode unitaire[95], and although he apparently seemed to share Laurent's views to the extent that both agreed that the arrangement could not be empirically determined, Laurent believed, as Brooke[96] pointed out, that by anticipating model building structures, it was possible to explain reactions. Gerhardt's types, on the contrary, were derived from reactions through a process of comparison, generalisation and abstraction and were merely a means of description and not of explanation as were those of Laurent. For Gerhardt each formula was an abbreviated and abstract description of the "metamorphoses"[97] of the substance under consideration.

Gerhardt's formulae in their final form were designed to emphasise formal analogies between compounds[98] on the basis of their chemical functions. Consequently, the formulae he established were to be depicted around a central atom, which being responsible for the typical properties, was therefore identified in the formulae.

2.1.2.- Wurtz: working out the heritage left by Gerhardt.

Although Gerhardt's system had been the implicit basis of Wurtz's investigations from the early stages of his career as chef d'école, the way in which Wurtz used it was made explicit in his book entitled Leçons de Philosophie Chimique[99] published in 1864. Apart from his articles published in the Répértoire de Chimie Pure, entitled "Observations sur la théories des types"[100] (1860) and the "Histoire générale des glycols" (1860)[101] or even his English paper "On oxide of ethylene considered as a link between organic and mineral chemistry" (1862)[102], in which Wurtz proclaimed the unification of chemistry, he never stated before so explicitly and comprehensively the construction of his theoretical framework as in this textbook. In fact, it corresponded to a balance sheet on the state of chemistry in which, after almost a decade as an established chemist and having gathered around him so many élèves, he showed how he had assimilated different contributions and put them into practice.

From the historical point of view and by establishing a genealogy of the main concepts he adopted, Wurtz as an advocate of theories developed by outsiders of the French establishment, nevertheless chose Lavoisier, the epitome of French chemistry, as the historical reference of his enterprise. Thus he located what he called the nouvelle chimie , i.e., that of the followers of Dumas, Laurent and Gerhardt, in a line of continuous progress within the classificatory tradition inaugurated by Lavoisier, despite the different basis of their classifications. Furthermore, by denying it any revolutionary insight, he integrated it in a "chain of progress":

> And maybe we are wrong in calling it nouvelle chimie, since this is still the chemistry of Lavoisier. If for 90 years the science he had created has exhibited such magnificent development, it is not due to any revolution, but to a continuous progress and this chain of progress was never disrupted.[103]

According to Wurtz it was within this line of continuous progress that Gerhardt introduced his classificatory system, which at its operational level embodied his type theory. The formulation of this theory went through several revisions to which especially Dumas, Laurent, Williamson, Wurtz himself and Hofmann[104] had contributed, although in different ways. But for Wurtz, above all

> Type theory and its associated notation are a marvellous instrument for description and classification, whose contributions to science are mainly its simplicity and clarity of form.[105]

The way in which this theory operated was to be summarised in the table Gerhardt published in the Annales de Chimie (1853)[106], which Wurtz reproduced in his book. Gerhardt had arranged chemical compounds following biological patterns, by organising them according to families, genera and species. In his chart compounds were grouped according to four fundamental primitive types - water type, hydrogen type, hydrochloric acid type and ammonia type, which had been established on an empirical basis, i.e., from the comparative study of the reactional behaviour. By providing a pattern of classification each compound was topologically located, since it could be inserted by analogy in one of the four types established in the chart.

GERHARDT'S TABLE

	EXTRÉMITÉ GAUCHE OU POSITIVE.	TERMES INTERMÉDIAIRES.	EXTRÉMITÉ DROITE OU NÉGATIVE.
Type eau....... $\left.\begin{matrix}H\\H\end{matrix}\right\}O.$	$\left.\begin{matrix}C^2H^5\\H\end{matrix}\right\}O$ Alcool.	....	$\left.\begin{matrix}C^2H^3O\\H\end{matrix}\right\}O.$ Acide acétique.
	$\left.\begin{matrix}C^2H^5\\C^2H^5\end{matrix}\right\}O.$ Éther.	....	$\left.\begin{matrix}C^2H^3O\\C^2H^3O\end{matrix}\right\}O.$ Ac. acétique anhydre.
	$\left.\begin{matrix}CH^3\\C^2H^5\end{matrix}\right\}O.$ Éther éthylméthylique	....	$\left.\begin{matrix}C^2H^3O\\C^7H^5O\end{matrix}\right\}O.$ Acétate benzoïque.
	....	$\left.\begin{matrix}C^2H^3O\\C^2H^5\end{matrix}\right\}O.$ Éther acétique.	....
Type hydrogène.... $\left.\begin{matrix}H\\H\end{matrix}\right\}$	$\left.\begin{matrix}C^2H^5\\H\end{matrix}\right\}$ Hydrure d'éthyle.	....	$\left.\begin{matrix}C^2H^3O\\H\end{matrix}\right\}$ Aldéhyde.
	$\left.\begin{matrix}C^2H^5\\C^2H^5\end{matrix}\right\}$ Éthyle.	....	$\left.\begin{matrix}C^2H^3O\\C^2H^3O\end{matrix}\right\}$ Acétyle.
	....	$\left.\begin{matrix}CH^3\\C^2H^3O\end{matrix}\right\}$ Acétone.	....
Type ac. chlorhydrique $\left.\begin{matrix}H\\Cl\end{matrix}\right\}$	$\left.\begin{matrix}C^2H^5\\Cl\end{matrix}\right\}$ Éther chlorhydrique.	....	$\left.\begin{matrix}C^2H^3O\\Cl\end{matrix}\right\}$ Chlorure d'acétyle.
Type ammoniaque. $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}Az.$	$\left.\begin{matrix}C^2H^5\\H\\H\end{matrix}\right\}$ Az. Éthylamine.	....	$\left.\begin{matrix}C^2H^3O\\H\\H\end{matrix}\right\}$ Az. Acétamide.
	$\left.\begin{matrix}C^2H^5\\C^2H^5\\H\end{matrix}\right\}$ Az. Diéthylamine.	....	....
	$\left.\begin{matrix}C^2H^5\\C^2H^5\\C^2H^5\end{matrix}\right\}$ Az. Triéthylamine.	....	....

NOTE: The bars in the symbols meant that the new atomic weights (C=12; O=16) were being used. The symbol Az stood for nitrogen.

Wurtz and his <u>élèves,</u> however, were to use an extended version of this table which included the condensed and the mixed types. The former had been introduced by Williamson (1852)[107], who suggested the convenience of adopting types resulting from the condensation of several water molecules and accordingly he related sulphuric acid to the double condensed water type

$$\left.\begin{array}{l} H^2 \\ H^2 \end{array}\right\} O^2 \quad \text{or} \quad \begin{array}{l} \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \end{array} \qquad\qquad \left.\begin{array}{l} (SO^2)'' \\ H^2 \end{array}\right\} O^2 \quad \text{or} \quad \begin{array}{l} \left.\begin{array}{l} H \\ (SO^2)'' \end{array}\right\} O \\ \left.\begin{array}{l} \\ H \end{array}\right\} O \end{array}$$

Water type (double condensed) — Sulphuric acid

Thus, two water molecules were seen as being both joined together by the radical $(SO^2)''$, which replaced two atoms of hydrogen of a molecule of water double condensed, as it is indicated by the number of dashes ("). The same reasoning was later applied by Wurtz to the formulation of glycerine (1855)[108], that he included in triple condensed water type in which three atoms of hydrogen are replaced by the radical $(C^3H^5)'''$.

$$\left.\begin{array}{l} H^3 \\ H^3 \end{array}\right\} O^3 \qquad\qquad \left.\begin{array}{l} (C^3H^5)''' \\ H^3 \end{array}\right\} O^3$$

Furthermore, this pattern also applied to any of the simple types, which could be condensed in this way. In addition, Odling introduced the category of mixed types, assuming that any element or polyatomic radical may link other molecules of a different nature giving rise, as for instance, to the following types:

$$\begin{array}{l} \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ HCl \end{array} \quad \text{and} \quad \begin{array}{l} \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ \left.\begin{array}{l} H \\ H \\ H \end{array}\right\} Az \end{array}$$

Coming back to Gerhardt 's table and his type, theory they were both supported by a system of notation in which the compounds were represented by assuming that they were formed by substitution through reactions of double decomposition, and as we said before the only ones Gerhardt admitted. Thus, the notation he developed had to account for these reactions and was itself an instrument to visualise the "active centre"[109] or functional part of the molecule, which for Gerhardt became itself a criterion for classification. However, in this later development of his theory he was introducing on the one hand a subjective factor in the identification of the functional part of the molecule and, on the other, his system was not responding consistently in the cases of compounds with several functional parts or even none. Moreover, when there was no agreement between chemical properties and the formulae ascribed analogically through the comparison of a certain compound with what was supposed to be its corresponding type, Gerhardt would classify according to analogy, despite contradictory empirical data.

Since Wurtz adopted Gerhardt's system, he obviously also inherited its major inconsistencies. As a chemist well aware of the work of his colleagues in France and abroad mainly due to his editorial activities both in the Annales de Chimie and later in the Bulletin de la Société Chimique de France, but also because he was constantly receiving in his laboratory young chemists who had attended the laboratories of Kekulé, Erlenmeyer and Kolbe he felt he should give guidance in the application of the scheme of his fellow Alsatian. In a way which denotes a special skill for organisation of available chemical information, he even sometimes reinterpreted data obtained by chemists who were completely opposed to his theoretical views, as we shall see in due course. Thus, unlike Gerhardt, besides substitution reactions, Wurtz also admitted reactions which take place through addition. Moreover, instead of concentrating exclusively on the functional group leaving aside the radical[110], he was to consider it for descriptive and classificatory purposes, because he attributed a great importance to the fact that notation could describe and make predictable the way in which compounds were generated. As in an example we may quote, that of the derivatives of acetic acid. Wurtz wrote:

when I adopt this formulation for the main derivatives of acetic acid the formulae

$$\left.\begin{matrix}C^2H^3O\\ H\end{matrix}\right\}O \qquad \left.\begin{matrix}C^2H^3O\\ K\end{matrix}\right\}O \qquad \left.\begin{matrix}C^2H^3O\\ C^2H^5\end{matrix}\right\}O \qquad \left.\begin{matrix}C^2H^3O\\ C^2H^3O\end{matrix}\right\}O$$

Acetic Acid	Potassium Acetate	Acetic Ether	Acetic Anhydride

$$\left.\begin{matrix}C^2H^3\\ H\end{matrix}\right\}S \qquad \left.\begin{matrix}C^2H^3O\\ CH^3\end{matrix}\right\} \qquad \left.\begin{matrix}C^2H^3O\\ Cl\end{matrix}\right\} \qquad \left.\begin{matrix}C^2H^3O\\ H\\ H\end{matrix}\right\}Az$$

Thioacetic Acid	Acetone	Acetyl	Acetamide

I am stressing that all have a common element; the radical acetyl C^2H^3O. It is the link which unites all these bodies; it reveals between them some sort of kinship [rapports de parenté].[111] (C=12; O=16)

On the whole, with this notation, theory accounted for the chemical transformations, that could be translated into equations, that he called équations génératrices [112]. Accordingly, reactions would become much clearer as soon as they were described by "typical" equations. He considered type theory as the symbolic representation of a larger number of reactions envisaged as double decompositions, as in the following example, in which the visualisation of the groups which remain permanent through the reaction (radical) and those which, being attached to the "active centre" (O), may be replaced with conservation of type:

$$\left.\begin{matrix}C^2H^3O\\ H\end{matrix}\right\}O \quad + \quad \left.\begin{matrix}C^2H^5\\ H\end{matrix}\right\}O \quad = \quad \left.\begin{matrix}H\\ H\end{matrix}\right\}O \qquad \left.\begin{matrix}C^2H^3O\\ C^2H^5\end{matrix}\right\}O$$

Acetic acid	Alcohol	Water	Acetic ether (ester)[113]

In addition and according to the above example, in the reaction between acetic acid and alcohol the production of the ester was necessarily related to the production of water and the underlying reasoning ultimately implied that these compounds could be "genetically" related. Furthermore, by comparing their chemical functions, their composition and also the corresponding place in the group to which a given compound or compounds belong, Gerhardt's table became for Wurtz and his école not only an instrument of classification, but indeed of prediction. On the whole Wurtz's interpretation allowed: a) the location of a given compound in a plan, which defined series or families where it could be inserted and b) the formulae to describe reactions, while the notation accounted for the functional parts and their interchange as well as for what was kept invariant, the radical c) that finally, both genetic and functional relations could be established and visualised between reagents and products. Thus, although Wurtz and his <u>élèves</u> were to explore Gerhardt's table in all its possibilities, they especially emphasised philogenetic relationships, unlike Gerhardt and closer to Laurent. If in the example presented above (acetic acid, alcohol, water and ester) both reagents and products were related, the reasons were not the same for Gerhardt and Wurtz. In Wurtz's terms this was due to the conservation of the radical, but in Gerhardt's they all belonged to the same type (water type) owing to the conservation of function. Moreover, looking at the "family" Wurtz defined for acetic acid and its derivatives (see above quotation) this deviation from Gerhardt's strict views became clearer. Compounds which in Gerhardt's terms would belong to different types, as for instance, acetic acid and acetyl chloride, given their different function (see Gerhardt's table), were assembled by Wurtz in the same family, because for him the criterion became the invariant group, i.e., the acetyl radical in this case.

As a matter of fact, since the 1850s Wurtz had adopted this approach regarding types, which emerged particularly in his discussion with Gerhardt about the classification of amides. Gerhardt included them in the ammonia type for functional reasons; Wurtz owing to his emphasis on philogenetic relationships regarded amides as derivatives of acetic acid. Accordingly, he defined in his memoir[114] the following family

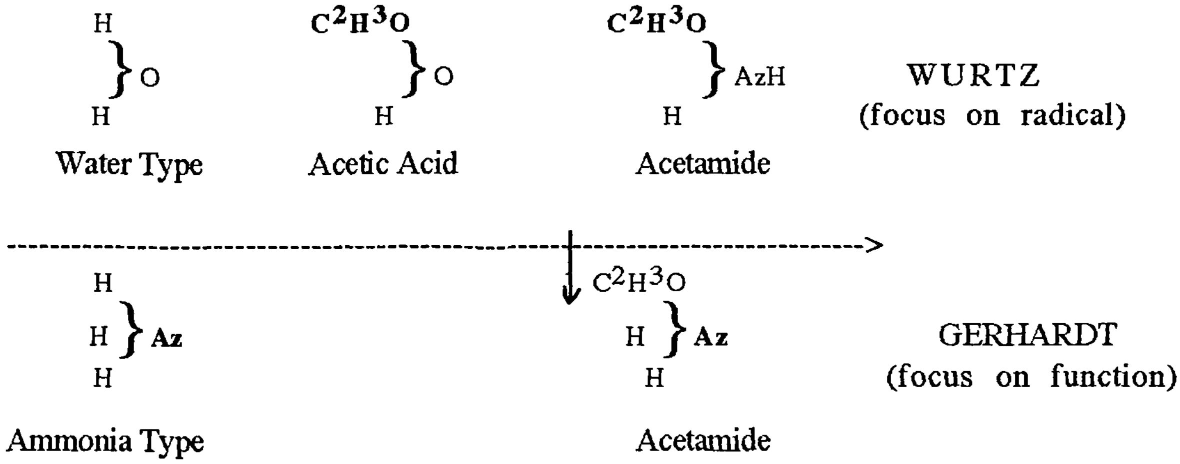
$$\left.\begin{matrix} H \\ H \end{matrix}\right\} O \qquad \left.\begin{matrix} C^2H^3O \\ H \end{matrix}\right\} O \qquad \left.\begin{matrix} C^2H^3O \\ H \end{matrix}\right\} AzH \qquad \left.\begin{matrix} C^2H^3O \\ H \end{matrix}\right\} Az(C^2H^5)$$

Water Type   Acetic Acid   Acetamide   Ethylacetamide

$$\left.\begin{matrix} C^2H^3O \\ C^2H^3O \end{matrix}\right\} O \qquad \left.\begin{matrix} C^2H^3O \\ C^2H^3O \end{matrix}\right\} AzH \qquad \left.\begin{matrix} C^2H^3O \\ C^2H^3O \end{matrix}\right\} Az(C^2H^5)$$

Acetic Anhydride   Diacetamide   Ethylacetamide

Hence, what in Gerhardt's table corresponded to a vertical movement from one type to another (from water type to ammonia type in this example), was for Wurtz a horizontal movement. In fact, he only follows Gerhardt for the definition of the type from which acetamide was derived (acetic acid), which is for this purpose classified in terms of function. But its derivatives obtained through "metamorphoses"[115] were considered independently from their function and referred to the type of the compound from which they were derived on the basis of the invariant group, the radical. The following scheme illustrates this question:



Based on these relations Wurtz defined families, which included all the compounds belonging to different types (in Gerhardt's terms) and possessing different properties, but whose common radical was kept in the various reactions they might be engaged in.

Taking the above example into account we may notice that with Wurtz the types of Gerhardt's table which had been established from reactional behaviour were converted into more abstract "prototypes"[116] (the water type became the "prototype" of acetamide), i.e., the substantialism still present in Gerhadt's abstract types nearly disappeared. This also applies to the condensed types insofar as, if the types of Gerhardt corresponded to existing substances (water, hydrogen, hydrochloric acid and ammonia), there is no such a thing as double condensed water. Wurtz was to push even further the abstract character of types as we shall see in due course.

On the whole if we compare the main features of Gerhardt's types with those of Wurtz we may conclude that, while Gerhardt emphasised the function, i.e., what changes throughout a sequence of reactions (diachronic), Wurtz emphasised the radical ,i.e., what is kept invariable (synchronic). Time was thus implicit, since each compound could not be dissociated from a succession of metamorphoses.

2.1.3.- The problem of radicals.

With his version of Gerhardt's system Wurtz launched a programme of research whose characteristics almost ensured some success to those who attended his laboratory, as their publications tend to show. Because it was empirically based, the prosecution of this programme involved a systematic study of reactions, but since Wurtz's école did not reject hypotheses and theory, but recognised them as desirable and necessary, theoretical refinements were introduced gradually and whenever empirically required. In addition, the systematic study of reactions, implying the establishment of analogies embodied not only the preparation of known and new compounds by using the capacities of prediction provided by the theoretical framework, but also the preparation of their derivatives as required by the necessity of defining "genealogies" of compounds. And, as mentioned above, these were organised in families according to a common radical. The definition of these genealogies through a succession of reactions, led to the notion that each compound had a history inherent to its study and a "family history", which was often translated in the titles of the articles ("Histoire générale des glycols", "Faits pour servir à l'histoire de l'alcool butylique", for instance). But, in practical terms, these genealogies led also to the establishment of general methods of preparation, which could be widely applied to analogous compounds.

In 1854 Wurtz took up butyl alcohol[117] again as a topic of research. This time he worked out the preparation of the corresponding ethers. For this purpose he prepared butyl ether by carrying out the reaction between potassium butylate with butyl iodide. Subsequently, he developed a sequence of reactions in which Williamson's reaction of etherification[118] was integrated. He also prepared esters (at the time also called ethers, for genetic reasons) from the action of butyl iodide on silver salts and pointed out the analogy between the groups $C^n H^{n+1}$ and metals, which suggests his concern in finding links between organic and mineral chemistry. In this way he established what he called the "Butylium" family, i.e., an exhaustive list of derivatives, which had in common the butyl radical[119]. This research on ethers together with the previous research on butyl alcohol led Wurtz to implement the method of preparing "ethers" (i.e. esters) based on the reactions between silver oxides or organic salts and alkyl iodides[120]. The extension of these investigations was also carried out by his élèves de Clermont, who prepared ethers using alkyl iodides obtained from alcohols and the corresponding silver salts[121]. Also Humann[122] and Moschnin[123] followed up the application of this type of reaction to prepare other compounds related to butyl and ethyl radicals.

As a corollary of the investigations mentioned above Wurtz was to systematise his views on organic radicals existing in alcohols and ethers in a memoir entitled " Sur une nouvelle classe de radicaux organiques" published in 1855[124] in which he reinterpreted two opposing views (Frankland and Kolbe versus Gerhardt and Williamson) on the monomeric or dimeric character of the hydrocarbon radicals isolated by Frankland and Kolbe (1848-1850). Wurtz's empiricism, but also his concern in deriving theoretical implications from experimental data, allowed him to reinterpret and subsequently accommodate in the terms of his theoretical framework data obtained by chemists advocating opposing theories. Thus, he was to reinterpret in terms of type theory electrochemical data of Kolbe and Frankland on the isolation of radicals[125]. He demonstrated that it was possible to prepare mixed radicals (R-R') taking into account Kolbe's and Frankland's assumption that radicals (R) were actually dimers R-R. In order to prepare these mixed radicals Wurtz put forward a reaction in which two different hydrocarbon radicals were combined after the decomposition of their respective iodides (seen as ethers for philogenetic reasons) by metallic sodium. This became known as the Wurtz reaction:

(e.g.) $$C^4H^5I + C^8H^9I + 2Na = \left.\begin{matrix} C^4H^5 \\ C^8H^9 \end{matrix}\right\} + 2NaI$$ (C=6, O=8)

With this memoir Wurtz concluded that he found a form of conciliating two theories long seen as opposed[126]: the theory of radicals, which he considered to have resulted from ill-founded observations, and the theory of substitutions introduced by Dumas and applied by Gerhardt in his system of classification as an operational device.

Wurtz was to retain from Kolbe's dualism, but without the original electrochemical framework, the notion of a radical as a complex unit, and associated it with the notion of function implicit in types. Consequently he accepted that besides substitutions (the only reactions admitted by Gerhardt) reactions may take place through addition. Furthermore, he generalised his conclusions and pushed even further the abstract character of Gerhardt's types, reducing them to three: MM, corresponding to the hydrogen type $\left.\begin{matrix}H\\H\end{matrix}\right\}$; M^2M^2, corresponding to the water type $\left.\begin{matrix}H\\H\end{matrix}\right\}O^2$ (O=8); and M^3M^3, corresponding to the ammonia type $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}Az$, which could appear in a double or triple condensed form. In this way he was also transforming the traditional dualism into a more complex one, since instead of a juxtaposition of two blocks or elements with opposed electrical charge without any further specification, he was introducing a dualism based on the complementarity of the pair radical/function, which were specified through comparisons of reactional behaviour. As the result of the requirements of his research, however, from now onwards Wurtz's approach is going to become gradually more focussed on the radical. The increasingly more complex radicals he was to deal with, often presenting isomeric relations, led to the introduction of another change. He had to focus not only on their composition but he was also constrained to consider the position of their constituent atoms, as we shall see in due course.

2.1.4.- Prediction.

The year 1855 was also to be the prelude to one of Wurtz's major discoveries of this decade, the discovery of glycol, which was to have the greatest impact on the development of research on polyatomic radicals carried out by him and his élèves. Thus, in his article "Théorie des combinaisons glycériques" Wurtz reinterpreted according to type theory data obtained by Berthelot[127] in his studies on the reactions of glycerine with fatty acids, and established the following analogy: if ethyl alcohol reacts with one equivalent of an acid to produce an ester and glycerine with three, then glycerine should be envisaged as a triatomic alcohol, since it comprises three equivalents of hydrogen, which may be substituted by three other groups[128]. In these conditions glycerine could be referred to the triple condensed water type and it was possible to formulate it as

$$\left.\begin{matrix} C^6H^5 \\ H^3 \end{matrix}\right\} O^6 \qquad (C=6;\ O=8)$$

Consequently, it could be located in Gerhardt's extended chart, but a gap was noticeable between ethyl alcohol, a monoatomic alcohol, and glycerine, a triatomic one, implying that a diatomic alcohol was missing in the scale of increasing complexity. In this way Wurtz was led to predict glycol, a diatomic alcohol which was exactly that "missing link"[129], and in 1856 he prepared it. The terms of this prediction are illustrated in the table below

WATER TYPE	ALCOHOLS
	ETHYL ALCOHOL
$\left.\begin{matrix} H \\ H \end{matrix}\right\} O^2$	$\left.\begin{matrix} C^4H^5 \\ H \end{matrix}\right\} O^2$
DOUBLE CONDENSED WATER TYPE	**GLYCOL**
$\left.\begin{matrix} H^2 \\ H^2 \end{matrix}\right\} O^4$	$\left.\begin{matrix} C^4H^4 \\ H^2 \end{matrix}\right\} O^4$
TRIPLE CONDENSED WATER TYPE	GLYCERINE
$\left.\begin{matrix} H^3 \\ H^3 \end{matrix}\right\} O^6$	$\left.\begin{matrix} C^6H^5 \\ H^3 \end{matrix}\right\} O^6$

* C=6; O-8

At a practical level, Wurtz took into account his prior research on butyl alcohol and the preparation of its respective "ethers", which generally speaking consisted of carrying out the reaction between alkyl iodides and silver salts, followed by a reaction with an alkali. He analogically applied it to the the preparation of glycol and after several attempts in order to determine the most appropriate silver salt and alkyl iodide, he concluded that glycol was successfully prepared by carrying out the reaction between silver acetate and ethylene iodide, which produces glycol diacetate, followed by the reaction of the latter with potash:

1) $$C^4H^4I^2 + 2 \left.\begin{matrix} C^4H^3O^2 \\ Ag \end{matrix}\right\} O^2 = 2\,AgI + \left.\begin{matrix} C^4H^4 \\ C^4H^3O^2 \\ C^4H^3O^2 \end{matrix}\right\} O^4$$

2) $$\left.\begin{matrix} C^4H^4 \\ C^4H^3O^2 \\ C^4H^3O^2 \end{matrix}\right\} O^4 + 2KHO^2 = \left.\begin{matrix} C^4H^4 \\ H^2 \end{matrix}\right\} O^2 + 2 \left.\begin{matrix} C^4H^3O^2 \\ K \end{matrix}\right\} O^2$$

(C=6; O=8)

This method was slightly modified by Wurtz himself, who instead of ethyl iodide began to use ethyl bromide, which is easier to prepare in larger quantities, and by his former élève Atkinson[130], who back in England, carried out the preparation of glycol by using potassium acetate, which was cheaper than silver acetate.

Having a general method of preparation and following analogical reasoning, Wurtz was able to prepare several homologues of glycol and as well as its derivatives and, in 1857[131], he achieved, for the first time, the artificial preparation of glycerine. With this research he laid down the basis for the research of his élèves, who engaged in the preparation of several glycol-related compounds following the above reasoning. However, for Wurtz the goal was not the compounds themselves, but the display of their genetic relations, because their knowledge implied that, potentially, any compound could be predicted and subsequently obtained. As he had pointed out,

> what is more striking in these experiments it is not the discovery of a new substance, the glycol: new compounds are dispensable in organic chemistry; nor was it the discovery itself and the difficulties overcame when glycerine was artificially produced. It is rather the way in which glycol was prepared and the predicted reactions which allowed the synthesis of this substance which was itself predicted.[132]

2.1.5.- Disagreement on types.

Couper, a Scottish élève of Wurtz, entered his laboratory in 1856, when Wurtz had just published his discovery of glycol, which gave great support to his version of Gerhardt's system. Thus, Couper's investigations carried out in the laboratory of the Faculty of Medicine resulted in a first memoir published in 1857 entitled "Recherches sur la benzine"[133]. This memoir, being closely connected with Wurtz's research on glycol and following his memoir "Note sur la liqueur des hollandais"[134], was based on type theory and aimed at converting benzene into phenol and glycol. Couper followed Wurtz's usual procedures, but he failed when he attempted to obtain phenol from dibromobenzene and silver acetate[135].

The following year Couper was to criticise types in his memoir "Sur une nouvelle théorie chimique" and these criticisms, far from being a question of detail, attacked the very basis of type theory. Moreover, its author claimed that a convenient discussion of Gerhardt's system could only be carried out on metaphysical grounds

> because it is only in overturning a general principle of research that the theory can be proposed.[136]

In fact, Couper was completely outside the <u>organic model</u> on which Gerhardt and Wurtz based their approaches. His point of departure was philosophical and very much related to Scottish common sense philosophy, particularly that of Sir William Hamilton. Scottish philosophy traditionally ascribed a fundamental role to imagination and conceptualization in the construction of scientific theories, which should be subordinated to a principle of simplicity and economy by reducing the number of their fundamental elements. In addition, those who were educated within this tradition, which also advocated the teaching of mathematics and particularly geometry for the training of the mind, tended especially to emphasise the philosophical foundations of their scientific fields[137].

When Couper, argued that

> "the end of chemistry is its theory. The guide of chemical research is a theory."[138]

he was not in contradiction with Wurtz's views on the role of theory, but their respective interpretations did not coincide. For Couper a theory had to fulfil two main requirements: to be empirically true and no less philosophically true. Although he admitted that type theory was for the most part empirically true, some few exceptions had been found: the peroxides did not fit into it and the principle of double decomposition could not be applied to the conversion of sulphuric and carbonic acids into their respective hydrates. But, instead of considering these examples as minor exceptions he was to use them as a sufficient argument to falsify the whole system. This argument was tied up with the philosophical principles advocated by his former professor of philosophy at the University of Edinburgh, Sir William Hamilton, who defended the idea that for a scientific system coherence was not enough, since it should conform both with direct experience and the rules of common sense. Consequently, a scientific system could be falsified either by establishing a self-contradiction or by proving to be inconsistent with an independent datum, i.e., with an independent well-established observation[139]. Thus and according to Couper, although operating on an analogical basis[140], type theory was unable to explain the above mentioned chemical questions and for this reason it should be rejected altogether inasmuch as in his opinion its foundations were false. For him, type theory, instead of explaining reactions described them, and the terms of that description, rather than being based on relations between atoms taken individually, was based on relations between groups of atoms. Moreover, he argued that it had as a starting point a generalisation from which every single case had to be deduced, which conferred on types an abstract character that Couper could not accommodate, both from the philosophical and chemical viewpoints. He particularly criticised the indefinite character of the simple water type, from which many compounds were derived, which could not be found in any definite body and the condensed version of the same type, which could not be found in nature as water. As he pointed out,

> should the principle which is therein adopted be applied to the common events of life, it will be found that it is simply absurd.[141]

As an illustration of his arguments he applied a linguistic metaphor, by claiming that if the principles of type theory were applied to systematise the combination of letters into the words that formed the contents of a book, it would imply the discovery of

> a certain word which would serve as a type, and from which by substitution and double decomposition all others would be derived.[142]

Although these principles could globally lead to an empirical truth, since the "type word" as a reference for analogy enabled the formation of new words and new books ad infinitum, Couper rejected them on the grounds of common sense as a criterion of validation. He says that

> a principle which common sense brands with absurdity is philosophically false and a scientific blunder.[143]

After these criticisms he pointed out a solution based on what he believed to be the "true method" both for science and everyday life, which consisted of

> throwing away all generalisation, of going back to first principles and of letting the mind be guided alone to reach the structure of words we must go back, seek out the undecomposable elements, viz., the letters, and study carefully their powers and bearing. Having ascertained these, the composition and structure of every possible word is revealed.[144]

It is clear that what Couper was seeking was not primarily a model of classification like his contemporaries. As he argued these were restricting chemistry to the study of the organisation of chemical bodies according to their decomposition, hindering the comprehension of their molecular composition. Instead, Couper's aim was a "more rational theory of chemical combination"[145] which could explain the constitution of bodies according to their composition and properties and, to achieve this goal, a method was required. Thus, to a model of classification of compounds based on the study of reactions (i.e., empirically based) he opposed a conceptual system which was to lead to the explanation of reactions themselves; to the study of the organisation of chemical bodies he opposed composition and structure. Consequently, instead of going from the whole to its parts he would go from the constituent basic units[146] to the whole, since he assumed that "the whole is simply the derivative of its parts"[147]. The method he suggested had been analytical in a preliminary stage because it was required to reach the most simple basic individual units and to determine their properties and "powers". According to his words:

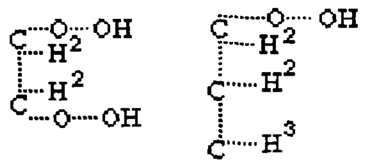
> when properties and powers of the individual are known, then it will be possible to know the constitution of the combinates (sic.), which their synthesis produces.[148]

Thus, his method implied the definition of an intrinsic and universal property,.i.e., the definition of an inherent and common property to all elements, on which Couper could lay the chemical foundations of his own system, which he aimed to be valid both for organic and mineral chemistry. For this purpose he assumed chemical affinity as the property to be considered, but he distinguished two sorts: "affinity of kind" and "affinity of degree". The first was the special affinity manifested between different elements (e.g. carbon for oxygen, chlorine, hydrogen etc.) and the latter corresponded to the limit of combination. The "affinity of degree", however, could vary, but since that property is common to all elements and its suppression would imply the destruction of their respective chemical character, Couper converted it into the very basis of his system. In addition, and as regards organic chemistry, he was to privilege carbon as a reference element owing to what he considered to be its distinguishing characteristics: it combines with equal numbers of different atoms such as hydrogen, chlorine, or sulphur and oxygen etc. and it enters into chemical union with itself in the most stable manner, the limit of its affinity of degree being 4. The second of these properties of carbon was, in Couper's opinion, pointed out by him for the first time[149] although he admitted that more evidence was required to ascertain if this characteristic was confined only to this element. However, he added:

> these two properties, explain all that is characteristic of organic chemistry.[150]

In this way Couper was disrupting the ties that linked organic chemistry to the organic world, not only by dissociating totally organic compounds from their natural origin (organisms), but also by dismissing the organic model which type theory used as a metaphor to frame the description and classification of organic compounds. Consequently, the definition of organic chemistry now became subordinated to a single chemical element, carbon, since Couper converted it into a basic structural unit.

In order to translate this approach, whose goal was not the description of how compounds react (type theory) but why they react, Couper had obviously to develop a completely different system of formulation from that used by the type theory. In his formulae a specific position was equally given to each atom and the bonds, which maintained the structure together, were also represented. As regards the representation of bonds, however, Couper's formulae presented some variations. Thus, in the memoir published in the Comptes Rendus, in which he first exposed his theory, dotted lines and brackets were used to represent the bonds; in its extended version published in the Annales de Chimie continuous instead of dotted lines were used and, finally, in the English translation of the Philosophical Magazine, he only used dotted lines, as illustrated by the following examples[151]:



Glycol   Propyl Alcohol

(C=12; O=8)[152]

These formulae emphasised the carbon-carbon bond and, given its affinity to itself, Couper aligned this element in a chain, distributing the others in this carbon-based fundamental structure. The distribution of these other elements was based on the assumption that the relations existing between them and the basic units which formed the structures had the characteristics of a dipole.

In this way Couper's theory allowed the compounds to be given a priori as autonomous entities, i. e.,independent from their chemical "genealogy". Unlike typical formulae, his formulae simply defined a set of positional relations between the minimum units of the compound. Although they possessed the capacity of transformation, each of them was not derived from a succession of metamorphoses of an original type, consequently, they were completely independent from time. Therefore they were absolutely synchronic, i.e., they were purely a spatial representation of carbon-based compounds, independent from their process of generation. But, while Couper's approach was utterly original, it was also utterly alien because it was outside not only the current and developing organic model but also its direct opponent, the electrochemical dualism, which Couper himself rejected[153]. For this main reason, his contemporaries were unable to understand his theory globally as an independent and alternative perspective which could be explored, and even less were they able to accept it fully. This became immediately evident from their incapacity to follow his underlying reasoning demonstrated by those who, like Butlerov[154], attended the meeting held at the recently founded Société Chimique (1858), where Couper first presented his theory before sending it for publication. Furthermore, the classical questions of priority over Kekulé, for which Couper was to blame Wurtz[155], and both Wurtz and Butlerov's negative responses have to be understood in this context. Particularly the first question is ultimately misleading, since Kekulé's approach started from type theory, thus within the organic model, and the comparison between both has been traditionally based on the question of who first claimed carbon's quadrivalency, i.e., by removing the problem from their respective and radical different theoretical context. Due to the absence of a platform where dialogue could take place, since Couper was speaking "a different language", his critics instead of looking at his theory as a whole, were obviously to decontextualise it and focused on questions of detail . Wurtz was no exception and as he argued:

> I should emphasise that the ideas put forward by M. Couper seem to me to be to be very ingenious and even acceptable if we leave aside some certain subsidiary hypotheses and clouds which frame his exposition. In my opinion his ideas do not seem to be in contradiction with the doctrine of radicals and even with that of molecular types against which he believes he should hit with a sword.[156]

He also disagreed with his élève on the basis that Couper's formulae were too arbitrary and far removed from experimental data and different in its aims from types:

> with our rational formulae we do not have the pretence to represent the intimate constitution of chemical combinations. Our formulae only represent the metamorphoses, i.e., the facts accessible to experience and demonstrated by it.[157]

In addition, Wurtz also criticised the discrepancies in atomic weights used by Couper, C=12 and O=8, which may arise from the fact that he never distinguished between equivalent, element, atom and molecule. Finally, since Couper's structures implied the assumption of electric dipoles, it is not surprising that Wurtz by removing his élève's views from its own context of production, considered it as an electrochemical theory of a different kind. Consequently, he integrated Couper's approach in the available alternative with which he was familiar, i.e., the model advocated by the dualists, and manifested his preference for Kekulé's formulae, since they were a result of the full exploration of his own model.

Couper's personal misfortune[158] prevented him from developing his theory and may have prevented others from developing it fully, despite the difficulties that might have arisen from the fact that the "letters" (to use Couper's metaphor) of the alphabet his theory required were only to be put in order ten years later by Mendeleev, in his periodical classification of the chemical elements.

2.1.6.- Agreement on atoms. Unification of chemistry.

As the result of the exploration of polyatomic radicals and related isomeric questions the strict use of types became problematic, and from c.1855 chemists were led to an approach in which the constitution of radicals became progressively more important. Radicals had to be dissected even further, which implied introducing atoms and ascribing positions to them, i.e., it became increasingly more necessary to refer chemical elements to atoms and to their inherent properties, notably atomicity (valency). This was transformed into an organising concept, since it was to be taken as the primary cause and justification of types themselves. Simultaneously, however, it was to constitute the first step which enabled chemists working within the organic model, to move gradually away from types, heading towards structures. This change in focus led Wurtz to declare in 1860 that

> The idea of types is after all an artifice, a pure convention. In my opinion it should be subordinated to a more fundamental notion, that of the atomicity of elements.[159]

Already in 1855, and following a paper published by Odling[160], Wurtz[161] had used dashes to indicate the tribasic nature of nitrogen (Az'''). These dashes were intended to express the number of atoms of hydrogen which one atom of an element was able to replace. But, for some time, the concept of atomicity was applied rather indiscriminately and was often mixed with ideas of basicity and affinity, all to express valency. Three years later (1858)[162], however, Wurtz claimed that the notion of "basicity of atoms" that Kekulé had presented in a paper recently published[163] was not particularly novel since it had been already explored by Odling, Williamson and Wurtz himself. He added that his synthesis of polyatomic alcohols had notably contributed to it with experimental evidence, at the same it gave support to the consideration of polyatomic elements. Wurtz's claim was, however, contested by Kekulé, who claimed that as early as 1854 he had pointed out the "dibasic nature of sulphur"[164]. Nevertheless, in the following year (1859)[165] Wurtz was to distinguish basicity from atomicity; the first was intended to mean the "capacity of saturation" and accordingly it depended not only on the number of equivalents of "typical" hydrogen but also on the electronegative nature of the oxygenated radical; the latter was related to "the molecular complexity of a body, or the state of the type to which it is referred"[166]. Later in his book La théorie atomique (1879) Wurtz was to develop comprehensively another distinction between atomicity which he now defined as

> the saturating capacity of atoms or their valency in combinations[167]

and affinity as

> the force of combination or chemical energy. It determines the intensity and the direction of chemical reactions, and is estimated by the thermal effects which these reactions produce. It varies essentially with different atoms.[168]

These fundamentally different properties of atoms, that he placed at the very foundations of chemistry, shared between them a common feature, i.e., their relative character. Both atomicity (valency) and affinity were not absolute, because Wurtz regarded them as depending upon the reciprocal interactions between atoms, which implied that each atom had to "adapt" to its neighbour[169]. In a more abbreviated way this distinction between atomicity and affinity had been put forward by Wurtz himself in the Dictionnaire de chimie pure et appliquée (1868)[170].

However, in the 1860s discussions over atomicity as a constant or variable atomic property had taken place, involving several chemists. In 1861, G. Carey Foster, a former élève of Wurtz[171] wrote that atomicity expressed the capacity of combination of elementary atoms and like their atomic weights was a property as "fixed as unalterable"[172]. Kekulé was associated with this view[173], but like Erlenmeyer, Williamson and his élève Naquet, Wurtz advocated a variable atomicity, disagreing with his British "friend and collaborator":

> In hydrocarbons like C^2H^2, C^2H^4, C^3H^4, etc.we may suppose that it is tetratomic and in order to satisfy the affinity of carbon to carbon either two or four units of combination are absorbed. But it seems preferable to me to admit that in these hydrocarbons carbon may

> exist in two states: in the state of diatomic carbon and in the state of tetratomic carbon.[174]

Moreover, as he was to acknowledge in 1864, he took Couper's notion of "affinity of degree" and argued that for each elementary atom atomicity could vary from a minimum to a maximum[175].

The assumption of constant atomicity had allowed Kekulé to postulate not only the tetratomicity of carbon but also to introduce a theory of unsaturated compounds by assuming the possibility of double bonds (1858) and both were to be fundamental for the development of a structural theory. But these same assumptions raised several problems especially when applied to inorganic compounds[176]. Wurtz and many of his most outstanding French élèves, such as Friedel, Scheurer-Kestner and Naquet, were to adhere to variable atomicity, both regarding inorganic and organic chemistry[177], which was consistent with their unified view of chemistry. In fact, Wurtz was to clarify his own concept of atomicity, by saying:

> This word [atomicity] expresses the actual combining capacity referring to a given compound, which can vary in other compounds rather than the virtual and absolute combining capacity of an element or of a group. I should emphasise, however, that the word capacity for combination does not seem to me the proper term. Accordingly, when referring to elements I would define atomicity as the equivalence of atoms, i. e., their value of combination or of substitution.[178]

And he added that the maximum combining power of an element, i.e., what it manifests in its saturated compounds should be distinguished from the combining or substitution value actually manifested in a given compound. Accordingly, the maximum combining power was invariable, but the substitution value may change. In this direction, Naquet was to provide an ingenious explanation of variable atomicity, arguing that :

> If one imagines for example certain hook-shaped appendages fixed to the atoms which can serve for hooking onto the corresponding appendages of other atoms, thus resulting in the formation of a compound, than it is clear that the number of hooks attached to a single atom would represent its absolute atomicity. Now if these hooks are not able to bond equally well with the appendages of other bodies, it is conceivable that the effective or relative atomicity of a radical could sometimes remain below its absolute or true atomicity.[179]

These considerations provoked a reaction from Kekulé, who invoked his hypothesis of molecular compounds[180] to support constant atomicity, and a controversy arose in which

Naquet, Erlenmeyer and Wurtz participated. Notably the latter argued that he did not deny the existence of molecular compounds of which water of hydration was an example, but he added that the only justification for the variable atomicities showed by organic radicals was the variable atomicity of carbon. Atomicity taken either as variable or constant provided a justification for types, becoming in this way a means of classifying organic compounds . At the same time, however, it allowed the transition from a taxonomic purpose to an approach which was to focus increasingly on constitution, which Kekulé fully developed[181]. One of the consequences, was the extension of this property to elements, leading to their subsequent classification. However, Wurtz was not to follow this path[182]. As Russell has pointed out, in the 1860s British chemists especially such as Odling, Williamson, Frankland and W. A. Miller attempted a classification of the elements on the grounds of their respective atomicities, despite the difficulties arising particularly from their view that atomicity was variable[183].

Discussions on atomicity as an inherent property of atoms progressed together with the discussion of another inherent atomic property, atomic weights. During the same year Wurtz had distinguished between atomicity and basicity (1859) he and his élèves began using in their publications[184] the atomic weights resulting from Gerhardt's reform of equivalents[185]. Furthermore, in 1860 before the Karlsruhe meeting, in his lecture on glycols delivered at the Société Chimique, the Alsatian chemist adopted them publicly, as it was to happen with many chemists following Gerhardt's line of thought. In the 19th century, questions on the consideration of atoms in chemistry had been introduced not in the framework of a pure discussion on the constitution of matter[186], but rather as a consequence of the exploration of the classificatory systems put forward by Dumas, Laurent and Gerhardt, and in the case of Wurtz, also as a result of the research carried out by him and by Williamson on polyatomic radicals[187]. If the necessity of considering atoms was primarily dictated by the extensive use of analogy to classify compounds, it was increased to the same extent that constitution became more important than composition for the establishment of distinctions between compounds with a similar qualitative and quantitative elementary composition.

Kekulé , then Professor at the University of Ghent, had the idea in 1859 of suggesting an international meeting in order to reach an agreement among chemists on theoretical opinions and conventions and for this purpose he established contact with Weltzien, at the time Professor at the Polytechnic School of Karlsruhe, and with Wurtz. Kekulé thought firstly of enrolling Wurtz in his initiative, because he had the opinion that his Parisian friend was the most suitable chemist for the purposes of this meeting. As he expressed it in a letter addressed to Erlenmeyer:

> Excellent chap! two people could not possibly agree more on science in a general way than we do...I am convinced that Wurtz is the most important personality, and if he takes a leading role the matter is already half won.[188]

In the Congress, Weltzien was to hold the post of General Commissioner, Wurtz that of Secretary and in 1860 the meeting took place in Karlsruhe. Among the participants, most of them leading figures of European chemistry, were also several élèves of Wurtz[189]. Various questions were discussed, as for instance, whether or not a distinction should be made between a physical molecule and a chemical molecule[190], but it was recognised that the starting point should be, as Wurtz pointed out, a discussion and hopefully agreement on the meaning of the terms molecule and atom[191]. In addition Kekulé emphasised the importance of a consensus on chemical notation.

The participants of the meeting could be broadly divided into two categories, the "equivalentists" (electrochemical dualism) and the "atomists" (chemical unitarism). It was difficult to find common ground for further work as there were very few equivalentists at the meeting[192]. Furthermore, there were some disagreements on basic questions among the latter. Cannizzaro was to be the chemist who, by harmonising physical with chemical data, clarified and systematised the views of the atomists and his role in this meeting was of major importance[193]. Wurtz was to follow this line of consistency between chemical and physical data on atoms and his école adopted the new atomic weights after the Karlsruhe meeting. During the following two years the symbols of elements in formulae were crossed by a bar to mean that the new atomic weights were being used.

According to Cannizzaro, Berzelius had established his system of equivalents on the basis of the rule prescribing that equal volumes contain the same number of atoms, which only applies to simple substances, and he never ascribed to atoms any importance for the establishment of formulae of organic compounds. Nor did he make any distinction between atom and molecule, since he had even confined the above rule to a small range of simple substances, i.e., those which exist naturally in gaseous phase, introducing a division between gases and vapours which was not consistent with physical data and could hardly be accepted by physicists. Berzelius could not accept that molecules of simple substances could divide and combine, and he assumed that two molecules entered as a whole in a combination, which contradicted Gerhardt's and Avogadro/Ampère's ideas. Hence, following the Berzelius tradition an equivalent[194] was a macroscopic invariant and it was defined as the weight of a simple body which combines with 100g of oxygen, when its inferior oxide is produced. Accordingly the equivalent for hydrogen was 12.50 and carbon was 75. Another version of this same principle was used in parallel and later exclusively. This consisted of dividing all the equivalents by that of hydrogen (12.50). Using this version the equivalent of hydrogen was 1, that of carbon 6, and that of oxygen 8.

The atomic weight, in its turn, was a microscopic invariant which itself could explain the regularities in combining weight proportions of elements, i.e., to each element corresponds a specific atomic weight, the atom being a chemically indivisible unit, which combines with atoms of other elements in small integral units. In Karlsruhe discussions on a consistent application of a chemical system based on this assumption were to become the main issue.

Cannizzaro argued that a discussion on formulae had to start from Gerhardt's types, but some modifications had to be introduced, notably atomic weights of metals had to be corrected. In fact, Gerhardt had been led to attribute to carbon the atomic weight of 12 and to oxygen 16, but he halved the atomic weights of metals. He had assumed that all metallic compounds had formulae which were similar to those of the corresponding hydrogen compounds. While this principle was applicable to alkaline monovalent metals (like K, Na) it could not be applied to divalent or trivalent metals (like Ca, Fe). These inconsistencies were explained, because Gerhardt had used Avogadro's theory only partially and his assumptions conflicted with the laws of specific heats[195] and of isomorphism[196]. Thus, Cannizzaro suggested a systematic use of vapour densities for the determination of molecular weights of either simple or compound substances, specific heats to check only atomic weights (not molecular) and isomorphism to ascertain analogies in molecular constitution. In support of this revision the recent work of Wurtz on glycol provided an important argument and Cannizzaro was to point it out when he discussed the atomic weight of mercury:

> As a result, the same reason that directed us to double the carbon atom also commits us to double the mercury atom. This comes down to saying that the amount of mercury expressed by Hg^2 in the preceding formulae[H^2, HCl, Hg^2 Hg^2Cl, Hg^2Cl^2] represents a single atom. In this case it is seen that the atom is equal to the molecule of the free body; and that in mercurous salts this atom is the equivalent of a single hydrogen atom, while in the mercuric salts it is the equivalent of two hydrogen atoms. In other terms, to employ the language generally in common use today, the mercury is monoatomic in the mercurous salts, but in the mercuric salts it is diatomic like the radicals of Mr. Wurtz's glycols.[197]

These were precisely the kind of analogies, between polyatomic radicals and metals that provided several chemists aligned with Gerhardt's tradition to claim the unification of chemistry on the grounds of a subordination of the mineral to the rules of the organic. Although Wurtz had expressed this aim in 1860[198] he was to proclaim this unification in England (1862), basing his arguments on the investigations he had carried out on oxide of ethylene[199] and making use of the notion of polyatomic metals introduced by Odling as well as the idea of Cannizzaro of regarding metals as expressed above.

Wurtz had obtained from glycol[200] oxide of ethylene $(C^2H^4)''O$ (1859), a compound analogous to "Dutch oil", which he formulated as $(C^2H^4)''Cl^2$. Since oxide of ethylene undergoes reactions such as the following: with hydrogen to form alcohol, with oxygen to produce glycolic acid, with water to form glycol and compounds such as the polyethylenic alcohols, he was to compare it to mineral oxides in terms of reactions, properties and constitution. Its own formula expresses these analogies, i.e., the ethylene plays the part of a diatomic radical, which is indicated by the dashes (") and can be compared with the oxides of barium, strontium, calcium, magnesium, zinc, mercury etc. Adopting the new atomic weights Wurtz was able to establish consistently several analogies, as for instance:

$$\left.\begin{matrix}Ag' \\ Ag'\end{matrix}\right\} O \qquad Ba''O \qquad \left.\begin{matrix}Sb''' \\ Sb'''\end{matrix}\right\} O$$

$$\left.\begin{matrix}C^2H^5 \\ C^2H^5\end{matrix}\right\} O \qquad C^2H^4O \qquad \left.\begin{matrix}C^3H^5 \\ C^3H^5\end{matrix}\right\} O$$

He extended this kind of analogy to more compounds, including those belonging to condensed water types such as the polyethylenic alcohols and other polymers obtained respectively by his élèves Lourenço and Maxwell Simpson. These were based on the property of ethylene, which consisted of "its power of accumulating in combination", producing compounds containing multiple radicals, i.e., belonging to types of increasing complexity. Wurtz compared them to a large number of silicates, which could be predicted and prepared on an analogous basis, and this was to be the line of research explored by his élève Friedel.

After presenting significant examples to support his views on the analogies between organic and mineral compounds, types being an instrument to establish them, Wurtz ended his speech by claiming:

> Such are the considerations which I have ventured to put forward on the analogies existing between organic and mineral compounds. I have endeavoured to follow out these analogies in the most various classes of bodies, and to express them in the typical notation, so well adapted to comparisons of this nature. I shall think myself happy if I have succeeded in impressing more forcibly in the minds of my auditors this truth, which everybody is ready to enunciate, but few have undertaken to establish by strict demonstration - namely, that, there is but one Chemistry and that the laws which regulate the constitution of Organic bodies apply with equal force to the compounds of Mineral Chemistry and Mineralogy.[201]

2.1.7.- The Representation of compounds and "dissolving" formulae.

The distinction between atom and molecule, the establishment of new atomic weights and the consideration of atomicity as an intrinsic property of atoms were closely associated with the increasing necessity of more discriminating formulae, which was imposed by the empirical approach like that adopted by chemists such as Wurtz and Kekulé. In fact, these auxiliary concepts were progressively introduced in Gerhardt's original framework as a result of the questions raised by empirical practice. In the case of Wurtz's école we may observe several stages in the development of a structural approach to organic compounds and, as a general feature we may say that the adoption of structural formulae was slow and cautious, which was also an effect of the constraints resulting from Wurtz's empirical approach. If Kekulé's type theory ended up by generating the basis of a structural theory, at the same time it also became its major internal stumbling block. Kekulé, for instance, was to use typical formulae until c.1869 because according to him, types often fitted the empirical facts, so there was no strong reason to abolish them[202].

As we mentioned with Wurtz this whole process was slower and more cautious[203], and we may identify a progression from types to structures, passing through an intermediate stage in which both approaches were put together, resulting in the usage of mixed formulae.

As far as I am aware the first time Wurtz discussed the necessity of introducing some greater specification in typical formulae was in 1863[204]. The question was to explain the cases of isomerism presented by certain derivatives of lactic acid, which Wurtz and Friedel had formulated as $\left.\begin{matrix}C^3H^4O\\ H.H\end{matrix}\right\}O^2$ [205]. According to Wurtz the two atoms of hydrogen played different roles, one was basic or positive because it could be replaced by a metal and the other was negative and this same situation occurred in glycolic acid. The explanation given by Wurtz was that glycolic acid was derived from the oxidation of glycol. In this conversion two atoms of hydrogen were replaced by one atom of oxygen and in the case of oxalic acid two more atoms of hydrogen were replaced by oxygen. Following this reasoning Wurtz was led to consider glycolic acid as monobasic and oxalic acid as dibasic. These compounds could be represented through the following notation[206], which expressed the successive substitution of hydrogen by oxygen.in the radicals as well as the "kinship" relation between these compounds:

$$\left.\begin{matrix}C^2H^4\\ H^- H\end{matrix}\right\}O^2 \qquad \left.\begin{matrix}C^2H^2O\\ H^- H^+\end{matrix}\right\}O^2 \qquad \left.\begin{matrix}C^2O^2\\ H^+ H^+\end{matrix}\right\}O^2$$

glycol   glycolic acid   oxalic acid

However, Wurtz made the remark that this notation could not explain how the introduction of oxygen in the radical affected the function of hydrogen, which was associated with the respective relative positions of the two atoms of hydrogen and of the atoms of oxygen located either in or outside the radical. But, as he mentioned, even taking into consideration the advantages of Kekulé's "graphic notation" he preferred to use typical notation. His argument was that, although he was convinced that the functions of the atoms of hydrogen were dependent upon their position regarding both the typical oxygen and that of the radical, he thought that maybe he was able to determine not the real position of atoms but their relations by following each step of the reactions, which produce the corresponding isomeric derivatives.

In a footnote, however, making use of the formulae

OH^-	OH^+	OH^+
CH^2	CO	CO
CH^2	CH^2	CO
OH^-	OH^-	OH^+
glycol	glycolic acid	oxalic acid

he gave an explanation which summarised the position of his école until the late 1870s, since what he and his élèves were to do was to split up or "dissolve" partially or totally the radicals when empirically required, i.e., when types could not explain empirical data . Therefore he argued:

> We see that the above formulae represent the carbon and hydrogen atoms separated from each other and surrounded by atoms of hydrogen and oxygen which saturate them. In fact, in reality it should be so and it is clear that those formulae express better the real grouping of atoms than typical formulae in which the atoms having the function of radicals are represented by a block in a condensed expression. But the notions available to us about both the constitution and the way in which these radicals are generated are so few and vague, that in many cases it would be necessary to pile hypothesis on hypothesis in order to represent this constitution by "dissolved" (dissoutes) formulae such as those above. When combinations rich in carbon are under consideration, these formulae would become not only arbitrary but so complicated that they would be an obstacle for any clear exposition and a challenge to the memory. Hence, I think that the moment to introduce these formulae in science has not arrived until more decisive synthetic experiments have clarified the mode of generation of these hydrocarbons as well as their derived radicals[207].

From the mid 1860s onwards similar views were often expressed by Wurtz's élèves. In particular Friedel and Ladenburg argued that during the last ten years chemists had to overcome the limits imposed by Gerhardt on their research:

> Those limits consisted of his claim that chemical formulae were only reactional formulae and that the constitution of bodies would remain unknown for ever. The discovery of isomeric compounds, sometimes differing from one another by their chemical properties forced chemists to find ways of expressing isomerism by formulae[208].

However, they added that the point was not the determination of the "geographical positions of atoms in space"[209], but rather their reciprocal relations. Although they both admitted the good results which arose from" imaginative constructions" as those put forward by Kekulé to represent aromatic compounds, they still thought they were too complex to be fruitful. Kekulé's formulae contradicted the principle of economy and simplicity that the école advocated[210], which consisted of grouping analogies in simple and abstract laws, and formulae should be derived accordingly.

But from the discussions on these issues in the writings of Wurtz and of his followers other reasons for not using structural formulae emerge. One was the chemical reaction itself, which was conceived as a dynamic process, i.e., it implied movements taking place in time and consequently it was assumed that neither types nor structural formulae (the latter being pure spatial representations (synchronic)), could account for reality. Wurtz had raised this question in relation to the impossibility of types to account for isomerism:

> at the moment in which the union of two groups takes place a molecular movement may occur which fixes the constitution that typical formulae cannot express.[211]

Also Tollens, an élève of Wurtz and prior to Kekulé, was to point out a similar argument about structures, when he delivered a lecture at the Société Chimique[212] in which he presented structural models built with balls (atoms) and wires (atomicities). Although he did not aim to represent either the position of atoms in space or its actual shape, he added that

> I am convinced that they represent the true arrangement between atoms in the way they follow each other and the affinities that link them at a particular moment.[213]

Armand Gautier, also an élève of Wurtz, incorporated structural formulae in an extended notion of type and he viewed them not as representations of compounds, but rather as a form of representing types themselves. He argued that in this assertion they would enable chemists to predict reactions, since

> they show the interatomic relations, the molecular structure, the constitution and in a certain sense the cleavages of bodies by radicals or migrating groups from one compound to another.[214]

and for this reason he defined them as équations de condition. As such, the above notions like these of Gautier, portrayed clearly the tension between structure and function, i.e., between synchrony and diachrony. Notably, Gautier's extended notion of type was consequently to imply a distinction between type and function: on the one hand

> the notion of type is to a certain extent associated with indetermination[215]

on the other, function

> is a positive notion, and it is independent of the type...the function of a body implies a set of general chemical potentialities, which are to vary gradually passing from a body to its analogous neighbour.[216]

Nevertheless, another question should be taken into consideration which relates to the very notion of structure, its reality and its representation. For Wurtz and the majority of his élèves a molecular structure was a three-dimensional entity which could not be expressed by any formulae, typical or structural, for two reasons: they were not yet ascertainable by experiment, and chemical reactions were dynamic processes. Thus, since formulae could not translate reality they were mere representations. These representations could be considered as structural formulae only if the aim was only to express on a plane the mutual relations existing between atoms, i.e., their organisation at a given moment on a flat sheet of paper, and that was the reason why they often called them graphic formulae. Until the 1870s, the formulae which dominated the articles produced by Wurtz's école are types, and occasionally mixed formulae, i.e., part of a compound is represented to indicate the relative positions of atoms linked by lines, expressing atomicity[217], the rest being in a typical form. In the first volume of the Dictionnaire de chimie pure et appliquée, structural formulae were already used, but exclusively to explicate questions of isomerism[218].

2.1.8.- The conception of an asymmetric carbon.

One of the major contributions from within Wurtz's école for the understanding of isomerism was the theory of asymmetric carbon put forward by his élève Le Bel in 1874[219]. A similar theory, however, was almost simultaneously and independently formulated by van't Hoff[220]. Both authors had been contemporaneous at the laboratory of the French maître, but they both argued that they never discussed their ideas on this matter[221]. Their sources of inspiration had been different, Le Bel's starting point was more essentially from Pasteur, and van't Hoff from Kekulé. In addition, Le Bel's approach is more empiricist and abstract, which denotes the style of Wurtz's école, while that of van't Hoff's is more conceptual and pictorial. Because Le Bel remained attached and worked at Wurtz's laboratory until the death of the maître, only his theory will be presented in detail as a product of the école.

Taking into account Pasteur's investigations on tartaric acid, in which he established the correlation existing between molecular disymmetry and rotatory power, Le Bel's aim was to ascertain the arrangement in the three dimensional space of the atomic components of optically active molecules. For this purpose he established two principles: the first stated that given a molecule of a compound, whose formula is MA^4 in which M is a simple or complex radical combined with four atoms A, these being replaceable by substitution, if three of them are substituted by simple or complex monoatomic radicals different from M, the compound obtained is disymmetric. The set of radicals R, R', R" and A are assigned to different material points forming a non-superposable block to its mirror image and, consequently, it presents rotatory power. The two possible exceptions would be either when the molecule showed a symmetry plane comprising the four atoms A, since the substituent radicals cannot alter the symmetry in relation to the plane, or when the last radical replacing A has the same constitution as the rest of the molecule and their effect compensates or is added.

The second principle prescribed that only if two radicals were replaced by R and R', a symmetry or disymmetry may occur depending on the constitution of MA^4. If the molecule had a symmetry plane containing the two atoms A which were replaced, this plane remains after the substitution and the compound is inactive. Since Le Bel also postulated that, if either a simple substitution of two or even three atoms produces a single and same derivative isomer, he was led to admit that the four atoms A are located in the vertices of a regular tetrahedron, whose planes of symmetry are identical to those of the whole molecule MA^4. In addition, he was also led to conclude that no disubstituted body possesses rotatory power. Here he differed from van't Hoff to the extent that, for the latter the central carbon had four atomicities directed towards the four apices of a circumscribed regular tetrahedron, while for the French chemist the four directions of carbon atomicity were not so fixed.

Through biochemical processes Le Bel was also able to separate the optically active component from a synthetic mixture of the two mirror image components of a compound (racemic mixture), containing an asymmetric carbon atom.

2.1.9.- Discussion of atoms in a French context.

The discussion on atomic theory which took place in the Académie des Sciences in 1877 constituted the climax for the opposition in chemical theory between Wurtz and his two adversaries Deville, but most especially Berthelot. Signs of this disagreement may be found also at the level of their respective élèves and, as an example, we may mention the debate on atomicity as a means of classification, published in the Bulletin of the Société Chimique in 1876, involving Le Bel and E. Bourgoin, an élève of Berthelot[222]. Le Bel was to advocate the views of his maître and gave an indication of the atmosphere which surrounded discussions of atomic theory in the French scientific establishment. In his own words:

> M. Bourgoin brought together in his memoir some of the objections against atomic theory, which we usually find in the discussions of that theory presented in theses and concours.[223]

Next year at the Académie Berthelot, in the role of the increasingly more powerful "official" savant, was to accuse Wurtz of identifying hypotheses and representations of phenomena with Science itself, and claimed that:

> faithful to the traditions of the école française I think that it is necessary to distinguish between such conceptions and true scientific laws.[224]

The tone in which Wurtz replied was challenging and reflected his international standing. He pointed out that:

> atomic notation is generally used in all European countries, not only for the presentation of scientific research, but also in teaching.[225]

In this way they set up the scenario of the debate. As regards organic chemistry, the discussion was to be of a domestic nature, in so far as it proceeded as if the Karlsruhe meeting had never occurred, and the emotion involved in the controversy reveals the strong ideological component of the whole debate.

A pretext for the debate emerged when Troost, a devoted élève of Deville, and actually professor at the Sorbonne, presented a paper entitled "Nouvelle méthode pour établir l'équivalent en volumes des substances vaporisables"[226]. In his article, Troost argued that several chemists had denied the existence of compounds whose equivalent corresponded to 8 volumes, because they assumed a priori that gaseous compounds correspond always to 4 volumes and whenever they found a density which was consistent with 8 volumes, they claimed that the compound underwent decomposition[227].

Wurtz decided to respond to Troost's claim and repeated the same experiments using Hofmann's apparatus[228] and arrived at contradictory results, but which were consistent with Avogadro's hypothesis. Thus, he concluded that hydrated chloral dissociates when vaporised and that the gramme-molecule occupies 4 volumes, resulting from the mixture of 2 volumes of anhydrous chloral and 2 volumes of water vapour[229].

Deville came into the debate to support his élève's views, by invoking a non atomistic interpretation of Gay-Lussac's law[230]. The fundamental question was of interpretation and was closely associated with the adoption of the principle of equivalence. Wurtz was thus to argue that:

> The maintenance of the principle of equivalence in chemical notation would make Science return to the time of Dalton, Wollaston and Richter. It would be anachronistic or even a regression, and Science never regresses.[231]

Already in 1866 Deville, the most eminent French inorganic chemist at the time, had sent a message with kind advice to Wurtz and his élèves in a lecture at the Société Chimique, where the Alsatian chemist and his associates were the leading and most active members:

> I ask my young colleagues to allow me to give them some advice: the brilliant work produced in our laboratories of organic chemistry, which are a reason for satisfaction of our national pride make me wish deeply that all the properties of the numerous bodies which have been discovered in those laboratories may be studied with scrupulous accuracy. Each of them will contribute to set a table for comparison, on which we will later place the materials to build up a physical theory of combination. I especially address this young and enthusiastic people of science and work, who give to the école of Mr. Wurtz such brilliance. I entreat them to disregard nothing in this direction which ensures the success in the attempts developed by thermodynamics to find the mechanical law of matter transformations.[232]

Deville 's aim was to bring affinity, which he considered the chemical property par excellence, under the rule of the "empire"[233] of general mechanics in order to make it accessible to numerical evaluations, i.e., in terms of work and heat measurements. His defence of a physicalist approach for chemistry considered as a natural science was carried out by reducing chemical phenomena to macroscopic mechanical principles and was summarised at the time by his argument:

> After all every chemical action only produces three types of effects: mechanical work, an electrical flow and heat.[234]

But in 1877 in the Académie Deville, a chemist identified with the Second Empire, abandoned the debate, letting it be taken over by Berthelot, the chemist of the Third Republic. After all, despite their political differences, they shared similar chemical theoretical views, although there is no evidence of any backstage agreement for the purposes of this controversy. Troost assumed the same attitude as his maître and, coincidence or not, after this incident he stopped his collaboration in Wurtz's Dictionnaire de chimie pure et appliquée.

From now onwards the debate was to be between two major protagonists, Wurtz and Berthelot. The first advocated the organic model, which exploring the internal arrangement of organic compounds through their dissection embodied the consideration of atoms at least as an hypothesis; hence it operated at a microscopic level. The latter advocated the physical model which, embodying the Berzelian mineral model, advocated equivalents and associated rules as a macroscopic and therefore observable truth. Berthelot's scientific theory and practice were more than anything else a matter of proving positivistic ideology[235] to be correct and, consequently, his scientific arguments were brought in to legitimate doctrinal claims, whose undeniable origins may be located in Auguste Comte.

The influence of Comte's positivism on savants and particularly on chemists can be traced back to Berzelius and even Liebig[236], but Berthelot was to become its leading representative in French 19th century chemistry. Berthelot's rejection of atoms and the defence of equivalents was based on the assumption that equivalents corresponded to observable and measurable macroscopic parameters through which reactions could be described and compounds formulated. The atomic considerations of his adversaries were the work of imagination and far too removed from reality, and he could neither see nor count atoms or molecules:

> There are here two hypothetical notions, that of atom and that of molecule. Whoever saw, I repeat, a gaseous molecule or an atom? The notion of molecule is undetermined from the point of view of our positive knowledge.[237]

In fact, Berthelot did not dismiss atoms as a physical hypothesis, but he rejected them in chemistry on the basis that they could neither be directly observed nor could their weight be directly measured, therefore their existence was hypothetical, a "mystical speculation". Furthermore, the determination of their alleged weight required the admission of Avogadro's hypothesis (law), which he also rejected, since in practice it implied the assumption of the physical reality of atoms and molecules. This was unacceptable for him because in his interpretation it would entail the subordination of chemistry not to physical laws but rather to physical hypothesis:

> I would like to talk about the confusion which tends to become current between the word law and hypothesis. For instance, Avogadro and Ampère formulated an hypothesis not a law by saying that: all gases contain the same number of molecules in the same volume. In reality, we cannot either see molecules or count them.[238]

Although to a certain extent, Berthelot like indeed Comte could accept atoms as an hypothesis necessary to a microscopic approach in physics, even so the aim should be to translate as soon as possible these hypotheses into macroscopic laws, through the measurement of observable physical quantities, i.e., through the assessment of "positive" facts. For Berthelot the case was rather a matter of consistency and articulation between chemical theory and macroscopic physical data, since in its macroscopic assertion physics like astronomy were paradigmatic examples of "positive" sciences. Hence, chemistry should be free from hypotheses and follow a similar path heading to the positive stage

> It is this happy situation that chemistry has not yet been able to achieve, as physics and astronomy already have [239]

However, each science should seek its own specific laws and in order to preserve chemistry's autonomy Comte had already pointed out the specificity of chemistry, arguing that

> we have physics proper and chemistry...all chemical action is in the first place subject to the influence of weight, heat, electricity, etc.; and it presents, in addition, something peculiar to itself which modifies the action of the preceding agents. This consideration, while it exhibits chemistry as necessarily following after physics, at the same time presentsit as a distinct science.[240]

What Berthelot was to declare later in 1879 in his Essai de mécanique chimique was to provide an explanation of his own solution in order to satisfy the positivistic requirements of on the one hand preserving the specificity of chemistry and, on the other, of transforming it in a positive science

> It was in 1864 that I engaged in thermochemistry: The studies I pursued until 1864, i.e., the synthesis of organic compounds was already accomplished, at least as regards both the comprehensive formation of fundamental compounds and the determination of general methods.[241]

But one reason why Berthelot made such a move from synthesis to thermochemistry seems to be rather the practical impossibility of proceeding within his substantialist vision of synthesis without the consideration of an atomic theory, than to an accomplished project. Moreover, his thermochemistry was the possible way out for him to be consistent with the constraints put upon his adherence to positivism in his scientific practice. Berthelot's thermochemistry corresponded to the linkage between "chemical action" and physical macroscopic agents, but since those agents could be modified by the specificity of chemical reactions the corresponding laws had to be derived accordingly. Here Berthelot had at his disposal the substantialist approach, which he had already used in his former project of unifying chemistry through synthesis.

> Instead of explaining chemical phenomena by these imaginary entities, carboxyl, sulphuryl, carbonyl, we shall see water formic acid, sulphuric acid and carbonic acid, the only bodies existing in reality, the only bodies which are able to participate in or result from reactions. On such a day, only an unique école of chemistry will exist, that of positive laws and knowledge, as that which already

exists for the sciences already definitively constituted.[242]

His aim until the mid 1860s had been to synthesize organic compounds from stable compounds or from elements. These elements, however, were not referred to their corresponding atoms, but rather to their substance and respective macroscopic proportional weights of combination, the equivalents. In his approach he had incorporated the available mineral model of Berzelius[243], which implied the subordination of the organic to the mineral:

> We may say that to express transformations in organic chemistry it is generally useful to refer the formulae of the bodies to the weights that occupy the same gaseous volume; all chemists agree on this point. The equivalent of carbon 6 may also be doubled and identified with its atomic weight 12, which simplifies all formulae. In organic chemistry there is some advantage in doubling the equivalent for oxygen and sulphur, but these advantages seem to be compensated in mineral chemistry because the new notation destroys the parallels existing between the reactions of chlorides, sulphides and oxides. It complicates the exposition of Science.[244]

Although Berthelot had applied his organic syntheses only to very simple organic compounds, and concluded that inorganic compounds could be prepared similarly[245], he was in fact applying to the organic the dualistic assumptions that had been derived from the analysis of the mineral. But, when he moved to thermochemistry this move ultimately implied that both the organic and the mineral could be assessed through the mechanical, by measuring <u>macroscopic</u> effects, as for instance the heat involved in chemical reactions.

For Berthelot, as for Deville, and indeed for Wurtz, chemistry was a natural science[246], but for the former it was so on the basis of a search for macroscopic regularities and analogies derived from empirical data without presupposing microscopic entities or hypothetical relations between microscopic parameters. Their empiricism could hardly allow the establishment of chemical rules based on hypotheses, since they believed that hypotheses should be avoided as much as possible, and could only be admitted as a precarious resource, but never as a basis from which chemical laws could be derived. As a natural science, chemistry should be classificatory, but only by relying on the <u>visible</u> and the <u>countable</u>.

Wurtz's position was from the beginning different and was that of someone who deliberately worked on an European level, despite the "domestic" pressures caused by his most direct competitors representative of the establishment and of the "positive and true" French scientific soul. In his reply Wurtz was obviously to align himself with Dumas and Gerhardt, but also with an international constellation of savants, ranging from Avogadro, Cannizzaro,Williamson and Odling to his German friends Hofmann and Kekulé, and exposed throughout the sessions of the debate the views that he had developed during his career. Thus, he was to advocate atomic weights and atomic notation in a unified chemistry, within an unified organic universe via a systematic establishment of analogies in which atomic notation had a fundamental role of display:

> The distinction that Mr. Berthelot established from the point of view of notation between organic chemistry and mineral chemistry seem to me to be ill-founded. A notation which is good for organic chemistry cannot be bad for mineral chemistry.[247]

Moreover, unlike his opponent, Wurtz advocated at a microscopic level consistency between chemical theory and physical laws, notably he considered as a law what Berthelot[248] saw as an hypothesis (Avogadro's). Wurtz was an empiricist, but not in the positivistic sense. His école, emphasised the value of hypotheses and advocated their heuristic role in science. They should be introduced whenever required to interpret empirical facts and coordinate experimental data in order to achieve general laws[249], which would enable scientists to make predictions. At this point hypotheses were to acquire the status of theories. In this sense chemistry was a natural science in its search for analogies, classificatory principles and general laws, but in a different way to that of his French colleagues. For Wurtz the analogies were not established at the level of the apparent or directly observed, i.e, the macroscopic, but on the basis of invisible structures, i.e., at the microscopic level. This brings in the question of the physical existence of atoms. Wurtz accepted that the notion of atom was an hypothesis[250] and as such implied a set of conventions as regards the representation of compounds. Despite Berthelot's accusations that he was taking these representations as plain reality[251] Wurtz was conscious of their conventional status, and he never claimed that other chemists should take them as real. However, as regards atoms it seems that he himself was prepared to accept their physical existence and therefore he recognised their ontological status[252]. In fact, if the diversity of substances was ultimately to be referred to the arrangement of their constitutive atoms and to their respective nature, it is perhaps not surprising that in the Dictionnaire de chimie pure et appliquée nothing had been said about the concept of element[253]. Thus, while Wurtz presented two articles concerned with the atomic theory occupying about thirty pages of his dictionary, no entry can be found for such a substantialist concept as that of chemical element; it is simply non existent.

2.1.10.- Research following the maître.

During the 30 years of chemical investigation developed within Wurtz's école, several characteristics emerge. One is the articulation between the research of the maître and that of the élèves, the other the relation existing between the work of the élèves themselves. This is revealed, not only by the analysis of the work produced, but also by acknowledgements, regarding suggestions of work, methods of preparation and techniques. Also the intimate relation between practice and theory is striking and in fact not only the école developed theory according to the line advocated, but also incorporated theoretical reformulations or further generalisations resulting both from internal and external scientific research. The interactions of Wurtz's école with others in Europe was not only due to Wurtz's engagements but also to the circulation of the many foreign élèves, which allowed the greatest interaction of ideas. Thus, some cases of élèves coming to Paris to develop research which had been initiated elsewhere may be found[254]. In addition, Wurtz's theoretical affinities with foreign chemists such as Hofmann and Kekulé, for instance, or with a former élève like Butlerov often led to almost simultaneous discoveries[255].

In order to show some of these relations a brief summary of the main research carried out by Wurtz and his élèves is given below. For practical reasons it is impossible to give all the appropriate references in this chapter. A comprehensive list of the articles involved is given in the general bibliography.

The research carried out by Wurtz's élèves from 1854 until the mid 1860s basically gravitated around glycol and oxide of ethylene, the latter as relating to projects leading to a demonstration of the unification of organic and mineral chemistry. The consideration of the theory of polyatomic radicals involved in these studies had as one of its most interesting consequences the prediction and subsequent preparation of polymers, but also provided strong arguments to the formulation of a theory of atomicity, and therefore to the consolidation of the atomic theory.

Thus, from glycol and glycerine several polymers were prepared by Maxwell Simpson but especially by Lourenço. Although the application of polymers in modern terms was far from the horizon of all these chemists, Lourenço was able to predict polyethylenic alcohols and polyglyceric "ethers" (the latter with another élève Reboul) on the basis of Wurtz's theoretical framework, notably the admission that reactions may undergo condensation. Moreover, Lourenço devised a general method of preparation of "ethers" (esters) of glycol. These esters, having two radicals of the same acid, were also prepared by Wurtz but using ethylene bromide on silver salts. Lourenço suggested that it was easier to obtain them through the action of an excess of an organic acid on glycol or on an ester, and his research extended from 1858-1861. Wurtz, on the other hand had synthesized polyethylenic alcohols using a different method from Lourenço , i.e., through the reaction between ethylene oxide and glycol (1859). Lourenço was to systematise the methods of preparation of polyethylenic compounds that he and Wurtz developed as follows: 1) from ethylene bromide on glycol, 2) from ethylene oxide on glycol, 3) from acids on ethylene oxide followed by saponification.

Analogically, from propyl glycol Wurtz also prepared propylene oxide (1859), lactic acid and, with Friedel, lactamide, esters and several polylactic compounds (1861).In addition Bauer prepared amylene oxide from amyl glycol (1860). Following this line of research, but now involving glycerine and related compounds was the research carried out by Sell (1865),Tollens (1868), Henninger (1869). Also studies regarding glycol, glycerine and ethylene oxide comprising derivatives, polymers and isomers and more effective methods of their respective preparation were developed by Nevolé, Hanriot, Wurtz, Norton and Tcherniak between 1876-1878.

Another branch of research was the exploration of alkyl halides which were seen as ethers and consequently related to alcohols within Gerhardt's water type. But other relations could be established, since these compounds could also be related to oxide of ethylene and its homologues. Consequently, it was possible to refer them to the simple and condensed hydrogen type, in which ketones and aldehydes were also included. As Wurtz pointed out

> We know that to a given alcohol corresponds a great number of compounds which are related through close kinship relations [liens étroits de parenté]. Simple ethers, compound ethers, aldehydes, acids, compound ammoniacs are derived from alcohols by straightforward reactions in which we see the alcohol radicals passing on intact from a combination to another or being modified by substitution. [256]

From the practical point of view halides of alkyle saturated, unsaturated and aromatic had a great importance in the development of general methods of preparation of other organic compounds. At the same time they raised questions of isomerism, drawing the attention of chemists to the constitution of hydrocarbons, particularly to the arrangement of their constituent atoms and this was to become a major issue from the 1860s onwards. In the exploration of both saturated and unsaturated halides of alkyl and hydrocarbons, taking into account the implications mentioned above, the following élèves were involved between 1858-1881; Butlerov, Simpson, Sawitsch, Reboul, Crafts, Caventou, Clermont, Friedel, Oppenheim, Silva, Nevolé, Grosheintz, Le Bel, Wasserman and Wurtz. The investigations involving aromatic hydrocarbons were carried out between 1853-1883 by Couper, Naquet, Michaelson, Lippmann, Luguinin, Grimaux, Tollens, C. Gundelach, Michael, Greene, Œschner de Coninck, A. Picté and Wurtz. Research on the preparation of aromatic hydrocarbons, notably the preparation of homologues of benzene was to receive a major contribution from Friedel and Crafts with their general method for the preparation of hydrocarbons, ketones, acids, etc. through the use of aluminium chloride in reactions of synthesis (1877-1884), for which their authors became famous among organic chemists. Taking into account the characteristics of the école in France, the lifelong attachment of Friedel to Wurtz, and their common initiatives at other levels, this work may be associated with Wurtz's école, despite the seniority and autonomy of both chemists.

The research carried out on alcohols within the école has its origins in Wurtz's isolation of butyl (isobutyl) alcohol and was developed between 1855-1881 by Humann, Crafts, Oppenheim, Tollens, Wheeler, Friedel and Œschner de Conink. Friedel notably discovered secondary propyl alcohol in 1862, which was related to his research on hydrogenation of ketones, Œschner de Coninck similarly prepared secondary hexyl alcohol (1875). Also Le Bel and Greene (1878-1881) prepared derivatives of alcohols by using the reagent zinc chloride, a reagent which had been introduced by Wurtz in an investigation of its action on amyl alcohol in 1863. In addition between 1873 and 1881 Le Bel also engaged in the stereochemical studies relating to alcohols, both natural and synthetic

Friedel worked in the investigations on aldehydes and ketones developed between 1858 and 1865, with which he aimed at showing the similarities between aldehydes and ketones. The investigations of Bauer, Beilstein, Simpson, Lieben and Frapolli were also connected with this same subject. Related to the investigation on derivatives of ketones that Fittig had carried out in 1859 obtaining pinacone (pinacol) from the action of sodium on anhydrous acetone, Friedel and Silva determined its constitution and Silva suggested an alternative method for its preparation (1873). Studies on derivatives of ketones were taken up again later, following the development of investigations on amines, by Œschner de Coninck and Pabst (1874), who tried to prepare methyl amine from the reaction of ammonia on acetone, and by Tcherniak and Hellon (1883) with their research on sulphocyanoacetone. In relation to the study of aldehydes, Wurtz himself tried in 1857 to obtain choral from the chlorination of acetal, but instead he obtained acetyl chloride and a chlorinated polymer of aldehyde. In 1872, together with his élève Vogt he was to take up this same question and they both obtained chloral from the chlorination followed by hydrolisation of a product obtained from aldehyde, alcohol and hydrochloric acid. This same year Wurtz was to conclude that in the reaction between aldehyde and hydrochloric acid an intermediate was formed that he formulated and called aldol[257]. From this aldol reaction a general method was derived, which allowed subsequently the preparation of homologues and derivatives. This investigation was complemented in 1883 by Wurtz with a study on the effect of heat on aldol and paraldol. On aldehydes there also worked, between 1881and 1883, Newbury, Hanriot, Œconomidès, Wurtz and Combes, who notably developed studies on crotonic aldehyde.

Between 1861-1867 research on several derivatives of various organic acids was carried out by Crafts, Buchanan, Menschutkin and Grimaux. Also Simpson prepared artificially succinic acid from ethylene (1860), and Wurtz, Friedel and Machuca synthesized and studied lactic, glyceric, and hydroxybutyric acids (1861). Later E. Gundelach studied quinic acid (1876) and Grimaux obtained parabanic acid (1873), barbituric acid (1879), and with Adam citric acid from glycerol (1880), which had been formulated by Salet in 1868.

As a result of Wurtz's commitment to the unification of chemistry other branches of research were developed in the 1860s, which were to deal with organometallic compounds, such as the investigations of Clève on ammines of platinous compounds, Menschutkin (1865), Gautier (1868) and Silva (1869), but mainly with silicon compounds whose preparation was extensively developed by Friedel, Crafts and Ladenburg (1863-1869). As Friedel was to point out in his lecture delivered at the Société Chimique entitled "Sur les composés du silicium" (1868)[258], the contributions of his maître to a unified chemistry had made possible his work and that of his senior colleagues, which was a demonstration of the importance of considering atoms even if as only an hypothesis. The preparation of silicon compounds had been carried out on the basis of its analogies with carbon, notably their identical atomicity. Also studies on inorganic compounds were developed and, among them we can mention, the investigations on thallium by Willm (1865), the study and attempt to establish the formula of fluoxyboric acid and respective salts carried out by Basarow (1874), the investigations on rare-earths performed by Lecoq de Boisbaudran (1875), which led to discovery of gallium, the studies on gallium that Dupré developed in Wurtz's laboratory under Boisbaudran's suggestion (1878), and the investigations on borotungstates by Klein (1880). In addition, and although associated with the école, but carried out independently in his laboratory at the Ecole des Mines we can mention the work of Friedel on mineralogy, especially the studies on the pyroelectricity of crystals (1860-1883) and artificial reproduction of crystals (quartz, albit, wurtzite, etc.)

Following Wurtz's early work on amines a new line of research on related compounds, notably derivatives of cyanogen was developed by Gautier (1865-1869), which culminated with the preparation of the compounds he christened as carbylamines, a parallel and isomeric series to that of nitriles, which he obtained from silver cyanide on alkyl iodides, and investigations on their derivatives were also carried out. In this line of research other élèves engaged such as Zaytsev (1865), M. Simpson (1867), Darmstaedter and Henninger (1870), Tcherniak and Norton (1876-1877), Hanriot (1878), Tcherniak and Nevolé (1878), Tatarinov

(1879), Morley (1880), Wurtz (1878-1881) and Plimpton (stereochemistry,1881).

Associated with all these experiments others with an auxiliary character were developed. Thus, for instance, improvements in the efficiency of laboratory techniques and apparatus, notably on glass material, which related to certain operations such as halogenations and fractional distillations (Wurtz, Le Bel and Henninger[259]); methods and apparatus for specific quantitative analysis (Dupré; Magnier de la Source); precision measurement instruments (Salet, Perrot). In parallel, auxiliary studies of fundamental importance from the theoretical point of view were carried out. Among them we should emphasise the determinations of vapour densities particularly relevant for their usage in the establishment of formulae, the measurement of crystallographic parameters often attributed to Friedel, optical measurements in stereochemical studies, especially used by Le Bel and partners, and spectroscopic studies which involved the discovery of new elements (Lecoq de Boisbaudran), the characterisation of elements in general and the related aspects on the constitution of matter (Salet). This kind of spectroscopic data as well as other of physical nature obtained by chemists and physicists both in France and abroad, whether or not associated with his école, was used by Wurtz especially in his articles on popularisation, in support of his views on the constitution of matter and on the cooperation and harmony of results between chemistry and physics

2.2.- The Establishment of biological chemistry.

The creation in 1874 of a separate laboratory for biological chemistry (chimie biologique) at the Faculty of Medicine, when Wurtz was Dean of the Faculty, corresponded to the recognition of this branch of chemistry at an institutional level, and was revealed in material terms by the allocation of a specific space and a separate director, Wurtz's élève, A. Gautier. But, if the creation of this laboratory may have been facilitated by Wurtz's position of power in the institution it may have been also more acceptable in a medical context than in a purely scientific one such as, for instance, that of the science courses held at the Sorbonne. Indeed it seems that biological chemistry as a field of research was not generally recognised by the French establishment, including Wurtz himself to some extent. Apparently, when Gautier had first devoted to studies on biological chemistry in the late 1860s, Wurtz had warned him of the "dangers" of engaging fully in a domain still obscure, which could damage his élève's career. His satisfaction with Gautier's experimental results and theoretical interpretations, however, may have contributed to the modification of his views[260]. This raises two interesting questions, not only on the relations between medical, physiological and biological chemistry but also the relations between "organic matter" (matière organique) and the chemistry of "organised beings" (êtres organisés). In order to understand Wurtz's views on these questions, some concepts he put forward in his two text books on medical and biological chemistry seem worth some consideration.

In 1864 Wurtz published for the ordinary students of the Faculty of Medicine his Traité élémentaire de chimie médicale, in which he also included notions on toxicology and the main applications of chemistry to physiology, pathology, pharmacy and hygiene, that were associated with his teaching duties[261]. From the chemical point of view this was very much a text book in which in an abridged form some basic theoretical concepts were given with particular reference to organic chemistry, the rest being practical laboratory analytical procedures to determine amounts of the several substances constituting "organised beings", a subject of interest for medical doctors. First Wurtz began by giving a definition of organic matter as follows:

> The substances that nature deposited in organs of vegetables and animals, to which we applied the designation of organic matter, embodied only a small number of elements. These elements are carbon, hydrogen, oxygen, nitrogen to which are added sometimes sulphur and more rarely phosphorus.[262]

Ascribing to these elements the capacity of associating in several different ways and proportions forming a multitude of compounds whose composition is fixed and whose properties are well-defined, giving them a distinct individuality, he called these compounds which were usually called "immediate principles" (principes immédiats) "chemical species" (espèces chimiques). These principles could be modified both by the "life processes" (procédés de la vie) and by artificial laboratory operations both of which produced less complex substances than those occurring in nature. Wurtz was therefore led to make an analogy between natural and artificial species through the common denominator of carbon in their chemical constitution:

> All this matter either created by nature or art, contains carbon. This simple body is the essential element of all organic substances, and we may say that organic chemistry is the chemistry of carbon combinations.[263]

In this way Wurtz's approach to "organised beings" consisted in a reduction of the "life processes" to their products, i.e., the chemistry of "organised beings" was subordinated and reduced to the chemistry of their constitutive organic substances. Located in a medical context, Wurtz's vision of biological chemistry was that of a special field of application of the more abstract acquisitions of organic chemistry, leaving completely aside speculations on the possible intervention of forces of a vitalist nature in "organised beings". Simultaneously, Wurtz's biological chemistry, by remaining inside the realm of the organic was also free from the imposition of physicalist reductionism, as that implied in physiology.

Although his book Traité de chimie biologique published in 1880, was partly an extension of the former book, its organisation was different, being based on abstract concepts derived from the various functions carried out by vegetable and animal organs. According to Friedel[264], Wurtz hesitated in the publication of this Traité owing to the complexity of the subject and to his recognition of the existence of many obscure points in the realm of the life sciences. However, he now introduced several refinements, which at least clarify his perspective of this field, notably by dissociating biological chemistry from its eventual medical, interest. Although subordinating the biological to the organic as he did before, he integrated his views in the context of a general vegetable and animal "economy". In its turn this interdependent vegetable and animal economy was encapsulated in a general economy of the globe. In this context he located in a chemical element, carbon, the possibility of life itself, by explaining the emergence of life on earth by the fulfilment of the conditions allowing carbon to form compounds. These compounds were those, which were not only involved in the constitution of the organs of plants and animals, but also those which generally speaking were involved in living processes. As mentioned before[265], such an interpretation based on assumptions of a materialistic nature did not trouble Wurtz's deep religious beliefs due to the way in which he dealt with science and religion. Consequently, he was led to define the object of biological chemistry as the study of the origin of organic compounds as well as of the conditions which underlay their formation, introducing in this way a historical dimension, which was emphasised in the title of the first chapter of this book, "Evolution of organic matter by the life processes"[266]. In his view of the biological Wurtz was to add that there existed an interrelation and a subordination between the animal and the vegetable kingdoms:

> Vegetables and animals are the recipients and the agents of life on the surface of the globe. If we consider in its essential the vital activity of the two kingdoms, we may say that plants have the power of elaborating organic matter, i.e., the immediate principles which constitute their organs. On the other hand animals, after having assimilated these immediate principles, have the task of destroying them. The animal kingdom is thus subordinated to the vegetable kingdom which supplies the former with the condition for its existence and the instruments for its activity, i.e., the ready made organic matter.[267]

Given this subordination he claimed that the most powerful manifestations of life should be sought in the vegetable kingdom, since he considered that the creation of organic matter was of a higher order than its destruction. However, these two processes, creation and destruction, were precisely the extremes between which Wurtz was to locate the phenomena involved in life[268], whose activity he defined as follows:

> The vital activity of organised beings consists of the formation of new cells, and consequently is essentially the elaboration of hydrocarbons and albuminoids.[269]

Wurtz's concepts associated with biology cannot be located in a purely French tradition, which assigned to reductionist physiology rather than to biology the framework to approach the phenomena of life. In the French tradition of Lavoisier, who had transposed his physical/chemical theory of combustion to the realm of the biological, a physical and chemical interpretation of functions such as respiration, transpiration and digestion and their complementarity in terms of an overall balance of matter and heat was provided. The term physiological chemistry[270] was thus in current usage in France throughout the 19th century, being closely associated with medicine and emphasised by the scientific weight of Claude Bernard. His more positivistic approach represented the physicalism advocated by the major figures of the French scientific establishment, who ascribed to macroscopic physics a paradigmatic role on which any approach in the realm of the natural sciences should be modelled.

In Wurtz's case the biological emerges from the organic through the establishment of distinctions and analogies between, on the one hand the vegetable and the animal and, on the other, between natural and artificial. His interpretation had been worked out from within the organic, but towards a further and more refined level of analysis, that at the microscopic level. Accordingly, his explanation of the biological in all its complexity, being carried out via the organic, was made ultimately dependent on the atomic:

> Questions of this kind will remain enigmatic for us to the extent that the atomic constitution of such matter is unknown or uncertain.[271]

Despite Wurtz's strong views on the unification of inorganic and organic chemistry under the rules of the latter, since in both the formation of atomic arrangements was subordinated to atomicity, he did not raise, however, a similar question regarding biological chemistry. This is explained because in his interpretation, although "organised beings" and "organic matter" belonged to different levels of approach, the first being the object of biology and the second of organic chemistry, both levels could be linked through biological chemistry. Thus, biological chemistry did not emerge as a separate branch of chemistry, but rather as intertwined with organic chemistry within an "organic universe", whose explanation depended ultimately on the inner atomic constitution of matter.

Wurtz's overall approach to biological chemistry was again consistent in many respects with the "organic universe" in the tradition of the German Naturphilosophen. Thus, his views resumed a historical and dynamic rather than a static approach to the study of life in nature, but without the intervention of inner forces as prescribed by Naturphilosophie. However, the level of his approach remained within the inner rather than in the external to the extent to which he made the explanation of "life processes" ultimately dependent upon the internal atomic constitution of organic matter (microscopic level). In this way, he dismissed on the one hand the external description of phenomena as advocated by those aligned with the French tradition whose paradigm was macroscopic physics, on the other, Wurtz did not invoke vitalist forces ,

2.2.1.- Research on biological chemistry.

It is in this context that the research carried out on biological chemistry within the chemical laboratories of the Faculty of Medicine has to be understood, i.e., in its intimate relation with organic chemistry, as well as in its eventual services to pharmacy and medicine. Particularly, in many respects it is hard to dissociate from organic chemistry the research of Wurtz's école on biological chemistry, if we take into account his concept of the latter. However, it is possible to single out some of Wurtz's work as well as that of his élèves with characteristics which were not so strictly related to the rest of organic chemistry.

Among the investigations of the maître we may mention those on fermentation, a domain of chemistry to which Pasteur contributed in both theoretical and practical aspects. In this field we may distinguish two stages in Wurtz's research, an early one concerned with the study of products of fermentation and a later one whose aim was finding a mechanism of action of ferments, which was to become later one of the central purposes of enzymology. As far as Wurtz was concerned, both aspects were supposed to lead to the artificial preparation of organic compounds biologically related. In the first stage we may include the investigations carried out in 1864 on the products of the fermentation of fibrin, in which he observed the formation of an albumen coagulating with heat. After these experiments he devised a method for the preparation of pure albumen through the precipitation of white of egg by lead acetate followed by the decomposition of the albumen so prepared by carbonic acid. A study of the transformation of fatty substances after crossing the intestinal villosities was also carried out, followed by the discovery of urea in chyle and lymph, and in 1867 he synthesized nevrin from the reaction of ethylene oxide and trimethylamine.

In the second stage we may include the research that Wurtz carried out together with the medical doctor Bouchut, the result of which was the discovery in the extract of Carica papaya of a ferment which digesting proteins was different from pepsin[272] (1869). These investigations on the composition and properties of this soluble ferment led Wurtz to an attempt to demonstrate the mechanism of the action of ferments. Thus, he claimed that it acts on fibrin in such a way that when this was washed and put in warm water or water made slightly alkaline, it is quickly digested, liberating the ferment which it had previously fixed. An analogy was also established between the action of ferments on proteins and that of acids and bases. Wurtz concluded that they cause the hydration of the protein in way similar to that of natural carbohydrates when they were decomposed by successive hydrations with mineral acids.

As regards Wurtz's élèves we can mention first, as related to biological chemistry in the way the maître understood it but clearly associated with the medical context, the investigations on the identification and chemical composition of extracts of plants carried out by Ramon de Luna in 1852 and E. Caventou in 1859. However, the latter seem to have been more directly inspired by his own father, since his work consisted of isolating alkaloids analogous or related to quinine given their eventual therapeutical activity. Later he studied with Willm the oxidation of cinchonine by potassium permanganate and isolated acid carboxycinchonic and hydrocinchonine. Also Daremberg studied questions associated with incomplete oxidation processes occurring in the organism and his experiments carried out at Wurtz's laboratory involved samples from patients of the Hôtel-Dieu (1870).

With his background in pharmacy Grimaux developed biologically related research between 1870-1881 as well as after Wurtz's death. Notably he investigated on pyruvic and malonic derivatives of urea and on citric acid with his junior associate Adam. In addition, Henninger carried out in 1878 research on peptones, showing that they can regenerate albuminoids under the action of substances causing dehydration, and improved the techniques of determination of nitrogen in urine. He also became responsible for the section on "physiological[273] chemistry" in the Bulletin of the Société Chimique.

Finally, we may mention that biological chemistry played a role in later careers of some of Wurtz's élèves. Thus, although while working with Wurtz Hanriot concentrated on organic chemistry questions in a strict sense, he later devoted himself to biological chemistry (from 1887 onwards). Particularly, in collaboration with Richet he studied biochemical phenomena involved in respiration and in 1896 he discovered a new enzyme, lypase, and developed studies on toxicology.

At the laboratory of biological chemistry, but under Gautier's supervision, Cazeneuve carried out research from 1874, which was not only related to strict organic chemistry but also to medicine and pharmacy, and particularly to toxicology. He thus collaborated in investigations resulting from Gautier's discovery of the alkaloids involved in putrefaction processes, the ptomaines. This research was continued by Gautier in 1879 with the collaboration of Etard, leading to the inclusion of these compounds in the pyridic and hydropyridic series. After Wurtz's death Gautier continued to make contributions in the field of biological chemistry with implications for general medicine, therapeutics and legal-medicine. Still related with Gautier's work on ptomaines are the investigations carried out by Gabriel Pouchet on the modifications produced in the chemical composition of certain secretions under the influence of cholera and the Koch bacillus, which in its turn were in connection with the subject of his former research on the ptomaines and leucomaines extracted from urine (1880). Although both investigations had not been carried out under Wurtz's supervision they were presented by him in the Académie des Sciences. Throughout his life Pouchet continued to investigate in biological chemistry, especially in aspects of interest for toxicology and legal medicine. The latter was to become the profession of Magnier de la Source who, while élève of both Wurtz's and Gautier's laboratories, developed apparatus to perform quantitative determinations notably in dry residues of organic secretions in 1880. Also Fauconnier devised in the same year a method for the determination of amounts of urea by using alkaline hypochlorides and hypobromides.

2.3.- Applied chemistry.

If, unlike Wurtz, we assume the existence of a clear-cut distinction between pure and applied chemistry (especially industrial and agricultural), then we may say that he himself did not contribute directly to this field in terms of research. His contributions were made rather through his reports and participations in meetings and exhibitions[274], his engagement in both the Société Chimique and in the Association Française pour l'Avancement des Sciences, publications such as his dictionary and the Bulletin, and finally, as adviser to his élèves involved in work or ownership in industry.

As mentioned earlier in this thesis, application of chemistry, particularly to industry were not carried out systematically at the laboratories of the Faculty of Medicine but in the factories and enterprises with which Wurtz's élèves of the "industrial wing" were associated. This research, whose main purpose was the improvement of technical problems especially relating to the textile and porcelain industries was, however, framed in terms of the theories of Wurtz's école. Moreover, as mentioned before, the élèves kept a lifelong attachment to the group in its multiple activities.

Among the investigations of the members of this industrial wing we may single out the contributions of the industrialist Scheurer-Kestner, who after his study on iron based dyestuffs in which he discussed iron valency in Wurtz's terms (1858), devoted himself in 1864 to the formulation of a theory of soda manufacture based on the Le Blanc process. He also studied the composition of green of Guignet (1865) and throughout his life he engaged in investigations dealing with coal and heats of combustion; industrial concentration of sulphuric acid; corrosion phenomena, and devised methods for the analysis of industrial smokes. Lauth also worked particularly in the field of dyestuffs and colours for porcelain associated with his ownership of factories in Alsace and with his directorship of Sèvres. He carried out research on aniline blue (1861) and invented violet of Lauth (thionine), which he prepared from the reaction of phenylenediamine and sulphur (1876). Also C. Girard, another industrialist, investigated dyestuffs related to aniline with de Laire in 1872, and at Wurtz's laboratory with E. Willm (1876) and Pabst (1880). He also dealt with questions of pollution and taxation involved in chemical industry (1872) in which he had disagreements with Lauth. On Berthelot's request[275] during the Franco-Prussian war, Girard together with Millot and Vogt carried out research on nitroglycerine and dynamite at Wurtz's laboratory (1870).

Among the foreigners those who also developed research related to industrial production of chemicals were Tcherniak and Norton, given their posts at the Compagnie Générale des Cyanures de Paris (c.1878-1883). Their main contribution to industrial chemistry was the preparation of thiocyanates and their transformation into ferrocyanides. While in Paris Tcherniak eventually associated with his research other élèves attending Wurtz's laboratory such as Nevolé (1878).

The <u>élèves</u> of Wurtz both foreign and French, who after leaving Paris devoted their careers to applied chemistry in agriculture but especially in industry, are presented in Appendix 1, showing that, although their interests were in the realm of applied science, their training had embodied basic research on fundamental organic chemistry.

NOTES TO CHAPTER 4.

1- See WILLIAMSON, A.W, " Charles-Adolphe Wurtz", Proc.Roy.Soc., 38 (1885), 22-34 (27), and FRIEDEL, C., "Notice sur la vie et les travaux de Charles-Adolphe Wurtz", Bull.Soc.Chim.Fr., 43 (1885), 1-80.
A description of this laboratory was provided by Friedel in a letter addressed to his parents on 24 November 1854, i.e., two weeks after his entrance in Wurtz's laboratory as a paying élève:

> L'entré du laboratoire est presque au fond à gauche, dans une grande cour que l'ont voit en passant devant l'Ecole de médecine. Nous nous tenons ordinairement dans la salle no.1 à côté de laquelle est une salle de cours qui communique avec elle et où sont les trois balances de précision. Souvent aussi nous sommes dans la cour, où, quand il fait mauvais, dans la salle no.3 où en ce moment même j'ai une préparation en train. La salle no. 2 sert aux préparations des cours et de plus on y dépose les fourneaux et bien d'autres objets. De cette salle une escalier conduit au 1.er étage où il y a encore une salle où se trouvent la machine pneumatique et d'autres instruments, puis les commencements de la collection. Cette salle doit être agrandie au printemps. Les murs sont couverts de posoirs et d'armoirs. Il y des tables dans tous les coins, et dessus et dessous, une infinité de flacons, de tubes, de creusets, de pinces, de capsules...(my italics)

Quoted from HANRIOT, M., "Notice sur la vie et les travaux de Charles Friedel", Bull.Soc.Chim.Fr., 24 (1900), 1 54 (4). Hanriot mentioned that 24 years later Friedel's description was still exact, since the extension of the laboratory predicted for that Spring (1854) had not take place, due to lack of funds.

2 The neighbours regularly complained owing to the noise caused by explosions. These happened quite often according to several sources, and sometimes involving accidents. See Friedel op.cit.(1), 14. Also FRIEDEL, C., "Notice sur la vie et les travaux de R.D. Silva", Bull.Soc.Chim.Fr., 3 (1890), 1-19 (15). Wurtz also mentioned the nature of such explosions and accidents, when he explained to Duruy the requirements of a laboratory:

> On est exposé à des accidents d'une autre nature lorsqu'on chauffe des liquides en vases clos à des températures très supérieures à leur point d'ébullition...On chauffe les tubes qui sont relegués dans un espace clos et spécialement consacré à cet usage: c'est le coin des explosions.

WURTZ, A., Les hautes études pratiques dans les universités allemandes, (Paris, 1870), p.9.

3- Friedel, op.cit.(1), 15.

4- A research laboratory for personal use was usually given to the Professor with a chemistry chair in the other higher educational institutions. But, in the Faculty of Medicine, due to the subsidiary role of chemistry in medical courses, this only occurred owing to Wurtz's nomination as Dean. As a consequence of this new position he obtained a higher budget, which allowed him to appoint officially two préparateurs to help him in his research. See PREVOST, A., La Faculté de médecine de Paris, ses chaires, ses annexes et son personnel enseignant de 1794 à 1900, (Paris, 1900), p.17 and 43.

5 See Chapter 2, section 2.3.

6- Friedel, op.cit.(1), 16.

7- See GEISON, G., Article Pasteur, D.S.B., vol. 10, p. 350-416 (352 353).

8 Letter to Dumas, 15 Feb. 1864, Paris, Archives de l'Académie des Sciences, Dossier Wurtz.

9 Light, air and neatness were for Wurtz major concerns in a laboratory and also the role of the garçon was often emphasised

> Ce serviteur dont les fonctions humbles mais si importantes, ont pour objet le mantien de l'ordre et de la propreté: j'ai nommé le garçon de laboratoire.

Wurtz, op.cit. (2), p.11.

10- Wurtz notably mentioned the following former élèves and now professors: Butlerov (Kazan), Beilstein (Göttingen), Luna (Madrid), Lieben and Naquet (Palermo), Carey Foster (Glasgow), Bauer (Vienna), Lourenço (Lisbon), Reboul (Besançon).

11- GAUTIER, A., "Ch.-Adolphe Wurtz, sa vie, son œuvre, sa personalité", Rev.Sci., 55 (1917), 769-781 (776). Also HANRIOT.M.; HALLER, A., et al., "Le centenaire de deux grands chimistes à Strasbourg, les alsaciens Charles Gerhardt et Adolphe Wurtz", Rev.Sci., 20 (1921), 573-602 (591).

12 This savant was Dumas.

13- Friedel op.cit. (1), 16.

14- See Chapter 2, section 2.1.

15- HJELM-HANSEN, N., "Une lettre inédite de A. Wurtz à J.-B. Dumas", Rev.Hist.Sci., 28 (1975), 259-265.

16- The "irregularity" consisted of the occupation of a public building for research carried out on private basis.

17- After his nomination as Dean in 1866, Wurtz was to promote immediately the nomination by the Ministry of Public Instruction of Dumas as Honorary Professor of the Faculty of Medicine, which may be seen as a measure to recognise and keep Dumas's support.

18 Dumas had been accused of neglecting his former élèves Laurent and Gerhardt and this incident was well known outside France.

19 This was the formula adopted to describe euphemistically the work that Berthelot's élèves had to carry out every morning for their maître's personal interest.

20- One of the rare examples is Wurtz's memoir "Recherches sur la loi d'Avogadro et d'Ampère", C.R., 86 (1878), 1170- 1175 (fn.1172) in which Wurtz mentioned about one of the experiments involved: " In these experiments I was assisted by Le Bel, Henninger and Dupré, who kindly watched them during the night".

21- GRIMAUX, E., "Adolphe Wurtz", Feuilleton de la République Française, 20 May 1884.

22 Acknowledgements from Wurtz to his élèves and vice-versa and between the élèves themselves were current to the extent that research of the members of the école was closely related and previous experiments provided the basis for subsequent investigations. Also some élèves, like for instance Friedel, specialised in certain areas like measurement of crystallographic parameters, or design of apparatus like Perrot, Salet and Le Bel and these were available for the use of others, who acknowledged them in their papers.

23 See Grimaux, op.cit.(21) and Hanriot ; Haller et al., op.cit.(11), 591.

24 Gautier, op.cit.(11), 776.

25 See next sections of this chapter.

26- Gautier, op.cit. (11), 776.

27 See Introduction, p..

28 Gautier, op.cit. (11), 776

29- Ibid. 777.

30 See Chapter I, section 3.3.

31 Mentioned in several sources. See for instance DUBOS, R., Pasteur, freelance of science, (London, 1951), p.60.

32 See for instance Grimaux, op.cit. (21) and GAUTIER, A., "Adolphe Wurtz", Rev.Sci., 21 (1884), 641-647

(645).

33- FRIEDEL, C., "Notice sur la vie et les travaux de Georges Salet", Bull.Soc.Fr., 12 (1874), 17-32 (18).

34- Hanriot; Haller et al., op.cit.(11), 591.

35- WURTZ, A., Les hautes études pratiques dans les universités de l'Allemagne, Autriche et Hongrie, (Paris, 1882), and Wurtz, op.cit (2).

36- WURTZ, A., "L'état des bâtiments et des services matériels de la Faculté de médecine de Paris", Rev.Sci., 1-2 (1871 1872), 852-854.

37- See for instance, Williamson, op.cit. (1), 18.

38- This process took place between 1877 and 1882. See Prevost, op.cit. (4), p.14.

39- These were the élèves of the hard-nucleus. See Friedel, op.cit.(1), 17.

40- For instance, Raoul Pictet participated in these seminars. He described his experiments on the liquefaction of gases, Rosenstiehl on colours theory, Henninger on Baeyer's investigations on indigo, Le Bel on his theory of asymmetric carbon etc. See Friedel, op.cit.(1), 17

41- Even for demonstrations during lectures Wurtz and his préparateurs Salet and Œschner de Coninck had to bring reagents and apparatus from the Faculty of Medicine, due to lack of facilities at the Sorbonne. See Friedel op.cit. (1),16 and op.cit. (32), 25.

42- See Friedel op.cit.(1), 16.

43 This report was sent to the Ministry in 1878, but was only published in 1882. Wurtz, op.cit.(35).

44- See PAUL, H., The sorcerer's apprentice. The French scientist's image of German science (1840-1919), (Gainsville, 1972), p.9 10.

45- WURTZ, op.cit.(35), p.4.

46 Ibid., p.2.

47- Wurtz, op.cit.(2), p.13.

48 Wurtz, op.cit.(2), p.11.

49 As for instance Pasteur, who claimed:

> Je vous en conjure, à ces demeures sacrées que l'on désigne du mot expressif de laboratoires. Demandez q'on les multiplie et qu'on les orne.

VALLERY RADOT, (edit),, Œuvres de Pasteur, (Paris, 1939), vol.7, p.200.

50 Wurtz, op.cit. (34), p.7.

51- See KAPOOR, S., "Dumas and Classification in Organic Chemistry", Ambix, 16 (1969), 1-65.

52- See de MILT, C., " Auguste Laurent. Guide and inspiration of Gerhardt", Jour.Chem. Ed., 28 (1951), 198-204.; FISHER, N.W., "Organic classification before Kekulé", Ambix, 20 (1973), 106-131; 209-233; BROOKE, J.H., "Laurent , Gerhardt, and the Philosophy of Chemistry", Hist. Stud. Phys. Sci., 6 (1976), 405-429.

53 See for instance, FISHER, N.W., "Kekulé and organic classification", Ambix, 21 (1974), 29-52

54 See Fisher, op.cit.(2).

55- See Fisher, op.cit.(53) .

56 Quoted from ROCKE, A.J., Chemical Atomism in the Nineteenth Century. From Dalton to Cannizzaro, (Columbus, Ohio, 1984).,p. 266.

57- See, for instance KLOSTERMAN, L., "A research school of chemistry in the nineteenth century: Jean Baptiste Dumas and his research students", Ann.Sci., 42 (1985), 1-40; 41-80 (53-54), and Fisher, op.cit.(52),131.

58- See, for instance, Rocke, op.cit. (56), 235.

59- Quoted from Fisher, op.cit (53), 48.

60- According to Jacob, the concept of organisation brought in a radical division among the objects in the world. Until the late 18th century, nature had been divided into three kingdoms, animal, vegetable and mineral. In this division objects were placed at a same level as beings, since it was considered that existed between mineral and vegetable, and vegetable and animal an almost gradual transition. See JACOB, F. The logic of life. A history of heredity (transl.), (London, 1989), p.86.

61- This was not exclusive of Lamarck. The concept of organisation was put forward almost simultaneously at the end of the 18th century by Vicq d'Azir, Jussieu and Goethe, for instance. The latter rearranged the products of nature into two categories instead of three, this being the only criterion for their distinction that of organisation.

62 Quoted from Jacob, op.cit.(61), p.86 87. Author's italics.

63- The designation of inorganic chemistry was scarcely used. Instead, mineral chemistry was widely used through the 19th century, and especially in France.

64- Although compounds could be obtained artificially in chemical laboratories, until the 1850s organic chemistry was still overwhelmingly engaged in isolating and identifying compounds from natural products.

65 See Chapter 1, section 4.3..

66 JAMESON, F., The prison house of language. A critical account of structuralism and Russian formalism, (Princeton, 1972), p.V (preface).

67 For instance, diethyl ether could not be distinguished from butyl alcohol, since both compounds have the same qualitative and quantitative composition. With type theory the distinction was possible on a functional basis. They could be represented respectively as

$$\left.\begin{matrix} C^2H^5 \\ C^2H^5 \end{matrix}\right\} O \qquad \left.\begin{matrix} C^4H^9 \\ H \end{matrix}\right\} O \qquad (C=12, O=16)$$

68 Radicals with the same composition but whose atoms were arranged differently. For instance, even with type theory it was impossible to distinguish between normal butyl alcohol and isobutyl alcohol.

69- In his Cours de philosophie positive Comte had claimed that the contribution of Wollaston had been invaluable for the transformation

> of the atomic theory into that of chemical equivalents, which offers a much more positive statement...they would definitely constitute a major improvement, if they are not reduced to a simple artifice of language, the actual concept itself remaining essentially unchanged.

Quoted from Rocke, op.cit. (56), p.74.

70 See Jacob, op.cit. (61), p.70.

71 See Jacob, op.cit. (61), p.85.

72- Quoted from Jacob, op.cit. (61), p.84.

73- See REHBOCK, P.F., " Transcendental Anatomy" in CUNNINGHAM, A.; JARDINE, N., Romanticism and the Sciences, (Cambridge, 1990), p. 146.

74- Ibid.,p.149.

75- See METZGER, H, La genèse de la science des cristaux, (Paris, 1969). Crystallography, is a science which emerged in the late 18th century with Haüy. Before Haüy the study of crystals consisted of the explanation of the physical and chemical processes leading to their genesis, with him the object of crystallography became the geometrical description of crystals, in a three dimensional space.

76- Ibid.

77- Jameson, op.cit.(60), p.VI (preface).

78 Klosterman , op.cit. (57), 56. Parallel to the situation of Dumas, who had studied botany during his youth in Geneva with Alphonse de Candolle; Laurent had studied crystallography with Biot and often also uses botanical metaphors; Wurtz had studied botany and was fond of reading in his maturity Lorenz Oken, whose writings Friedel considered "nuageux"; Kekulé studied botany with Schnittspahn, director of the botanical garden of Darmstadt, while student of the local Gymnasium. The models brought from the sciences de l'organisation, to use Dumas's expression, were decisive for the formulation of 19th century chemical thought.

79 Ibid.

80- URBAIN, G., "Jean-Baptiste Dumas (1800-1884) et Charles-Adolphe Wurtz (1817-1884). Leur rôle dans l'histoire des théories atomiques et moléculaires", Bull.Soc.Chim.Fr., 1 (1934), 1425-1447 (1431).

81- LAURENT, A., "Classification chimique", C.R., 19 (1844), 1089-1100.

82 Ibid., 1096-1098. Also KAPOOR, S., "The origins of Laurent's organic classification", Isis, 60 (1969), 477 527.

83 See Brooke op.cit (52), 426.

84- See Fisher, op.cit.(52), 106.

85 Similar views were expressed by Kekulé and Berzelius:

> We readily agree with the belief of Berzelius that "in a text book the most rigorous possible arrangement is of the essence; for textbook purposes we must seek a classification by which chemistry may most easily be grasped, and best retained in the memory". Although a certain flexibility of classification is permissible in a textbook, the book must be arranged overall according to a single point of view, if the primary aim is to be a general overview.

Quoted from Fisher , op.cit. (3), 45. In addition, it is also striking that Mendeleev, who considered himself a "confirmed disciple of Gerhardt", while he was writing his textbook Principles of Chemistry (1868) he sought for a system of classification of the elements. See PARTINGTON,J.R., A history of chemistry, (London, 1964), vol.4, p.894 and TILDEN, W.A., "Mendeléeff memorial lecture", Journ.Chem.Soc., 95 (1909), 2077-2105 (2104).

86 Quoted from Fisher, op.cit. (52),210.

87 See Jameson, op.cit.(60), p. 4.

88 See LOVEJOY, A., The great chain of being: a study of the history of an idea., (Cambridge, Mass, 1933).

89 Quoted from Fisher, op.cit. (52), 211.

90- Ibid., 212.

91 Homologous series were formed by a succession of compounds differing by CH^2, whose members presented similar properties and underwent similar reactions allowing prediction as Gerhardt pointed out.

92- See Fisher, op.cit. (52), 213.

93 See de Milt, op.cit. (2), Brooke, op.cit.(52), Fisher, op.cit.(52), Kapoor, op.cit. (82).

94- Partington, op.cit. (85), vol.4, p.414.

95 Ibid., p.415.

96- See Brooke, op.cit. (52)

97- Partington, op.cit. (85), 415.

98- Brooke distinguished Laurent from Gerhardt in their respective use of analogy in classification: material analogy (Laurent) and formal analogy (Gerhardt). See Brooke, op.cit. (52), 426-427.

99 WURTZ, A., Leçons de philosophie chimique, (Paris, 1864).

100 WURTZ, A., "Observations sur la théorie des types", Rép. Chim. Pure, 2 (1860), 354-359; 3 (1861), 418-421.

101 WURTZ, A., "Histoire Générale des Glycols" in Leçons proféssées à la Société Chimique de Paris, (Paris, 1860).

102 WURTZ, "On oxyde of ethylene considered as a link between organic and mineral chemistry", Jour.Chem. Soc., 15 (1862), 387-406. Paper presented in London in the Chemical Society.

103- WURTZ, op.cit.(99), p.217.

104- See Wurtz's own interpretation on the contributions of these chemists in op.cit. (97), p.85-100.

105 Wurtz, op.cit., (99), 112.

106 GERHARDT, C., "Recherches sur les acides organiques anhydres", Ann.Chim., [3], 37 (1853), 285-342 (339).

107 WILLIAMSOM, A.W.,"On the constitution of salts", Jour.Chem. Soc., 4 (1852), 350-355 (353).

108 WURTZ, A., "Théorie des combinaisons glicériques", Ann. Chim., [3], 43 (1855), 492-496.

109- Expression that I borrowed from Fisher, op.cit. (52), 220.

110 Wurtz, op.cit., (99), 101.

111 Ibid.

112 Ibid.,103.

113 The designation of ethers embodied the modern ethers, halides of alkyl and esters due to similar methods of preparation, i.e., due to "genetic" reasons.

114-WURTZ, "Mémoire sur les éthers cyaniques et cyanuriques et sur la constitution des amides", Ann. Chim., [3], 42 (1854), 43 69. This paper was a systematisation of "Sur le dédoublement des éthers cyaniques", C.R., 37 (1853), 180-183 and "Sur la théorie des amides", C.R., 37 (1853), 246-250. In these memoirs the formulae are doubled for carbon and oxygen (C=6; O=8), since Wurtz only adopted the new atomic weights in 1859. Amides were prior included in ammonia type by Hofmann and Gerhardt included them as such in his table.

115 Wurtz's very Goethean term for reactions. See, for instance, op.cit., (99), 221.

116- Term widely used within the sciences of organisation, particularly, transcendental anatomy.

117- In 1852 Wurtz isolated and identified butyl alcohol from potato oil. See Chapter 2.

118- See WURTZ, A., "Nouvelles observations sur l'alcool butylique", C.R., 39 (1854), 335-338. Also "Mémoire sur l'alcool butylique", Ann.Chim., [3], 42 (1854), 129-168.(more detailed version).

119- See Wurtz, op.cit. (120), 337-338.

120- See Wurtz, op.cit. (120),154.

121 CLERMONT, P., "Note sur la préparation de quelques éthers", C.R., 39 (1854), 338-340. Also "Mémoire sur les éthers phosphoriques", Ann.Chim., [3], 44 (1855), 330-336., (more detailed).

122- HUMANN, E., "Faits pour servir à l'histoire de l'alcool butylique", Ann.Chim., [3], 44 (1855), 337-342.

123- MOSCHNIN, W., "Ueber den Caprylalkohol", Lieb. Ann., 87 (1853), 111-117.

124- WURTZ, "Sur une nouvelle classe de radicaux organiques", Ann.Chim., [3], 43 (1855), 275-312.

125- Notably Kolbe had obtained the butyl radical by carrying out the electrolysis of potassium valerate, i.e.,from a completely different method.

126 Despite this attempt of conciliation, the two theories and their respective supporters remained opposed for longtime.

127- WURTZ, "Théorie des combinaisons glicériques", Ann.Chim., [3], 43 (1855),492-497. Wurtz claimed that the comparison that Berthelot had made between the "ethers" of glycerine with salts of ortho-, pyro- and metaphosphoric acids was not correct and, instead the analogy should be established with the three series of salts of orthophosphoric acid, described by Graham in 1833. Berthelot was to claim priority despite Wurtz's acknowledgement and emphasis that he was giving a different interpretation.

128- Ibid., 492.

129 The expression "missing link" was coined by E. Geoffroy St. Hilaire to mean intermediate species and explain the transition from the plan of invertebrates to that of vertebrates as a theoretical requirement of his defence of a fundamental unity of the Universe. Curiously Farber was led to use it, apparently without any reference to the French anatomist. See FARBER, E., "The glycol centenary", Jour.Chem.Educ., 33 (1956), 117 (117). Wurtz used the word bridge:

> Les glycols au nombre de quatre aujourd'hui, rangés en une série parallèle à la série des alcools proprement dits, étroitement unis par la composition et l'ensemble de leurs propriétés physiques et chimiques, et formant pour ainsi dire le pont entre les alcools et la glycérine, de même que leurs combinaisons marquent le passage entre les éthers et les corps gras.

WURTZ, A., "Sur l'oxyde d'éthylène", C.R., 2 (1859), 101-105 (104).

130 ATKINSON, E.,, "On monoacetate of glycol and on the preparation of glycol", Phil. Mag., 16 (1858), 433-438.

131 WURTZ, A., "Sur la formation artificielle de la glycérine", Ann.Chim., [3], 51 (1857), 358-367.

132 Wurtz, op.cit. (129), 104.

133 The only three articles published by Couper appeared in the usual French journals and were also translated into English. For practical reasons I will refer them to their facsimile included in ANSCHUTZ, R. "Life and chemical work of Archibald Scott Couper", Proc Roy.Soc. Edin., 29 (1909), 193-273.

134- WURTZ, A., "Note sur la liqueur des hollandais", C.R., 45 (1857), 228-230.

135-The cyclic structure of benzene had not yet been established.

136-Couper, op.cit. (133), 242.

137- See OLSON, R. Scottish philosophy and British physics 1750-1880, (Princeton, 1975), p.5 and 25. We should also note that the strong points of Couper's education had been philosophy, theology and languages rather than science.

138- Couper, op.cit.(133), 240.

139- Olson, op.cit. (137), p.143.

140- Ibid., p.147.

141 Couper, op.cit (133), 242.

142 Ibid., 244.

143 Ibid.

144 Ibid., my italics.

145- Ibid., 246.

146 Ibid., 244.

147 Ibid.

148- Ibid., 246.

149 Kekulé misunderstood Couper about carbon "quadrivalency", inasmuch as this property was constant for Kekulé and variable for Couper , although the limit the latter established was four. In his paper Couper only claimed that he would be probably the first to point out that carbon combines with itself in a stable manner. See Anschutz, op.cit. (131), 201.

150 Couper op.cit. (133), 248.

151 Ibid., 256 and 258

152 Couper was mixing the equivalents of Gerhardt and of Berzelius.

153 Couper rejected the theory of radicals, because according to his opinion it stopped the analysis at the level of the group of elements (radical) instead of going to each of the constitutive elements. In this theory radicals were seen as "quasi-elements" possessing an ultimate power which could not be explained. See Couper, op.cit. (133),244.

154- To Butlerov is often given credit of having introduced the word structure in chemistry. Even assuming that he did it, it had been within Gerhardt's type theory, i.e., as a result of the decomposition of polyatomic radicals like Kekulé, and in different terms from those of Couper. However, what Butlerov called structure was peculiar to him and was not the whole formed by the elements and bonds, but instead, the bonds themselves established by the capacity for mutual union inherent in atoms. See BYKOV, G.B., Article Butlerov, D.S.B., vol.2, p.621.

155 According to the testimonies of Lieben and Ladenburg, who both attended Wurtz's laboratory, their maître was not responsible for the delays in publication of Couper's theory in the Comptes Rendus, which led Kekulé's to claim priority over Couper. Because Couper accused Wurtz in rude terms, the latter was led to ask him to leave the laboratory. See Anschutz, op.cit. (133),200-201.

156- Wurtz, in op.cit. (133),218.

157 Ibid.

158 According to Anschutz, Couper showed from his youth mental instability, associated with deep religious concerns. In his short scientific career besides his failure to establish his theory, his experimental work on salicylic acid was also contested by Kekulé and Kolbe, although without reason , according to his biographer and former student of Kekulé, Anschutz. Couper soon retired in Scotland, apparently due to mental illness, being looked after by his mother for the rest of his life. See Anschutz, op.cit (133), 193-199.

159- WURTZ, A., "Nouvelles observations sur la théorie des types à l'occasion de la note de M. Sterry Hunt", Rép..Chim. Pur., 3 (1861), 418-421 (419). His italics.

160- See RUSSELL, C.A., The history of valency, (Leicester, 1971), p.92.

161- WURTZ, A.,"Sur une nouvelle classe de radicaux organiques", Ann. Chim., [3] 44 (1855), 274-313 (306).

162 WURTZ, A., "Observations sur la théorie des types", Rép. Chim. Pur., 1 (1858), 20-24 (24,fn.).

163- KEKULE, "Ueber die Constitution und die Metamorphosen der chemishen Verbindungen und über die chemische Natur des Kohlenstoffs", Ann.Chem Pharm, 106 (1858), 129-159.

164- The problem was solved easily and Wurtz admitted his friend's priority. See WURTZ, A., "Mémoire sur les glycols ou alcools diatomiques", Ann. Chim., [3], 55 (1859), 400-478 (479).

165 Russell, op.cit.(160), p.84 mentioned that Wurtz made this distinction in 1864, but in fact it had been made in 1859. See WURTZ, A., "Sur la basicité des acides", Ann.Chim., [3], 56 (1859), 342-349.

166- Wurtz, op.cit. (165).

167- WURTZ, A., The atomic theory (transl.), (London, 1888), p.224.

168- Ibid.

169 Ibid., p.227.

170 WURTZ, A., (edit.), Dictionnaire de chimie pure et appliquée, (Paris, 1869), vol.1, p.448-449.

171 Carey Foster had been also élève of Williamson and Kekulé. See Chapter 3 and Appendix 1.

172 See Rocke, op.cit. (56), p.300.

173 Ibid., p.300 301.

174- Wurtz, op.cit. (159), 420.

175- Wurtz, op.cit. (99), p.136, fn..

176 See Russell, op.cit. (160), p.180 186.

177 Mendeleev's periodic table by bringing together elements like sodium and copper, for instance, meant that they shared at least one valency state, drawing attention to the possible monovalency of copper, and reinforcing the views of those who championed variable valency. See also FRIEDEL,"Sur une combinaison d'oxyde de méthyle et d'acide chlorhydrique", C.R., 81 (1875), 152-155 (152), and SCHEURER-KESTNER, A., "Mémoire sur une nouvelle classe de sels de fer, et sur la nature hexatomique du ferricum", C.R., 53 (1861), 653 658 (653).

178 Wurtz, op.cit. (99), p.154. His italics.

179- Quoted from Rocke, op.cit.(56), p.302.

180- It seems that to a great extent this theory was developed by Kekulé in order to uphold his views on fixed valency. Unlike Naquet, who regarded sulphur, selenium and tellurium as tetravalent under the form of chlorides, Kekulé advocated that these chlorides were an aggregation due to physical forces and their components could be freed by vaporisation. See ibid., p.300; Russell, op.cit. (159), 190-193; FREUND, I., The study of chemical composition (London, 1904), p.532.

181- See Russell, op.cit. (160), chapt.8.

182- Russell, op.cit.(160), p.138.

183- Miller, for instance, was to classify according to the lowest atomicity manifested by chemical elements. Although in these attempts there was no correlation between atomicity and a periodicity with increasing atomic weight they drew attention to this property, which had been absent from those who were working out a classification based on atomic weights. Although, atomic weight was the organising principle adopted by Mendeleev for the classification of the elements, he and also Lothar Meyer were to take into consideration atomicity. See Russell, ibid., p.138.

184- See Wurtz, op.cit., (164),400-478.

185 Berzelius had considered the equivalents of organic acids the weights combining with one equivalent of organic oxide to which he attributed the formula AgO. Thus, all his molecular weights of the acids alcohols etc. became doubled. Gerhardt drew attention to organic double decomposition reactions in which there is elimination of C^4O^4, H^4O^2 and N^2H^6(C=6; O=8), or a multiple of these quantities, and he suggested that the equivalents of several elements should be doubled in inorganic chemistry. He subsequently suggested that the equivalents in organic chemistry should be halved.

186 Fisher, op.cit. (52), 106.

187- As Wurtz argued :

> Les expériences relatives à la formation et à l'interprétation que j'ai cru pouvoir leur donner ont, sinon introduit dans la science, du moins précisé et considérablement développé la théorie des radicaux polyatomiques. Le germe de cette théorie existait avant 1856; mais il me semble que depuis mes travaux sur les glycols elle a acquis une importance qui a aidé au progrès de la chimie organique depuis cette époque. (his italics)

Wurtz, op.cit.(101), 138.

188 Quoted from Rocke, op.cit. (56), p.292.

189 See Chapter 3, and Appendix 1.

190 See, NYE, Mary Jo, The question of the atom: from the Karlsruhe congress to the first Solvay conference, 1860 1911, (Los Angeles, 1984),p. xiv-xv.

191 Ibid., 15.

192 See Rocke op.cit. (56), 299.

193- See Nye, op.cit. (190), p.30.

194- The term equivalent became widespread with Wollaston in 1814. In order to determine equivalents Wollaston chose a single equivalent for each element and with these values he calculated molecular formulae.See Rocke, op.cit. (56), p.12.

195 The Avogadro's/Ampère law had a limited applicability due to the considerably small number of elements existing in the gaseous state. Dulong and Petit's law of specific heats was particularly useful since it applied to solids. According to it the specific heat of a body was indirectly proportional to its atomic

weight. After Cannizzaro's clarification, through vapour densities it was possible to determine the weight of molecules, and specific heats are a means of verifying the weight of atoms. In Gerhardt's system the inconsistencies occurred mainly with metals, whose atomic weights he halved.

196- Mitscherlich established that compounds with an equal number of atoms disposed in in the same way, crystalise under identical forms. The similarity of external forms results from the similarities of internal structure.Thus, isomorphism reveals analogies in the constitution of molecules. According to Cannizzaro the inconsistencies of Gerhardt's system enhanced the differences in criteria in mineral and organic chemistry. Unlike organic chemistry, mineral chemistry ascribed great importance to isomorphism and thus the same substance presented different formulae from the mineral or the organic points of view.

197- Quoted from Nye, op.cit.(190), p.24.

198- Through type theory he had claimed that

> les lois relatives à la composition et à la structure moléculaire des combinaisons organiques s'appliquent aussi aux composés.

Wurtz, op.cit. (101), p.133.

199- Wurtz, op.cit. (102)

200- Ibid., 387.

201 Ibid., 406. My italics.

202 In his opinion only when types could not account for the facts such as in the cases of unsaturated and aromatic compounds other formulae should be used. Although he did not deny the possibility of structural formulae to be determined, Kekulé denied that they could be taken as corresponding to the spatial arrangement of atoms. As Russell argued this was not an overall denial of a theory of structure, but the establishment of its limits, since at the time it was difficult to define a structure when steric matters were still uncertain. See Russell, op.cit. (160), p.144.

203- Certain historians like Russell and Fisher have suggested that Kekulé adopted a cautious position in publishing his theoretical views to avoid troubles with hostile colleagues, having in mind what happened to Gerhardt and Laurent. As regards his formulae, for instance, he used them already in his lectures and personal notes long before developing considerations on them in publications. It is plausible to think that Wurtz might have adopted an even more cautious approach justified by his French environment, although direct evidence was not found.

204- WURTZ, A., "Sur l'isomérie dans les séries glycolique et lactique", Ann.Chim., [3], 67 (1863), 105-113.

205- In the above article the symbols of the elements had a bar in the original to mean that new atomic weights were in usage.

206- This notation had been introduced by Heintz.

207 Wurtz, op.cit. (204), 108 109. His italics.

208- FRIEDEL, C.; LADENBURG, A.,"Sur un hydrocarbure nouveau", C.R., 56 (1863), 1083-1086 (1083).

209- Ibid.

210 As voiced by Wurtz and by Friedel, especially. See for instance FRIEDEL, C.,"Sur les composés organiques du silicium" in Leçons de chimie professées devant la Société Chimique de Paris, 1868-1869 (Paris, 1870).

211 WURTZ, A., "Recherches sur quelques hydrogènes carbonés", C.R., 56 (1863), 354-359 (356).

212- TOLLENS, B., "Sur quelques hydrocarbures de la série aromatique", in Leçons de chimie professées devant la Société Chimique de Paris, 1868 1869 (Paris,1870), p.196.

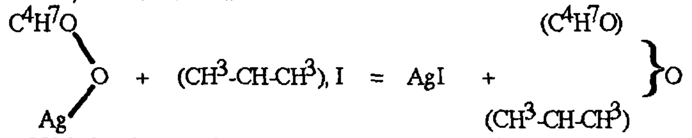
213- Ibid., My italics.

214- GAUTIER, A., "De l'acide cyanhydrique de ses homologues et de leurs isomères" in Leçons de chimie professées devant la Société Chimique de Paris, 1868 1869 (Paris, 1870), p.151.

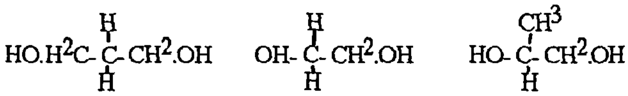
215- Ibid.,p.152

216- Ibid.

217- See, for instance Silva's mixed formulae for the reaction between silver butyrate and isopropyl iodide



SILVA, "Sur quelques composés isopropyliques: butyrate et valérate d'isopropyle", C.R., 68 (1869), 1476-1478.(1476). One the other hand, one year before Buchanan did not use types because he was ascertaining isomers of glycol.



Propyleglycol (II) Glycol ordinaire Propyleglycol (I)

BUCHANAN, J.Y., "Sur l'acide chloropropionique", C.R., 66 (1868), 1157-1160 (1159).

218 See Wurtz op.cit. (169), p.456-457.

219- LE BEL, J.A., "Sur les relations qui existent entre les formules atomiques des corps et le pouvoir rotatoire", Bull. Soc.Chim.Fr., 22 (1874), 337-347.

220 VAN'T HOFF, "Sur les formules de structure dans l'espace", Arch. Néerl. Sci. Ex. Nat., 9 (1874), 445-454.(French translation).

221- See their respective obituaries in the general bibliography and Russell, op.cit.(160), p.161, for instance.

222- BOURGOUIN, E.,"De l'atomicité comme principe de classification", Bull.Soc. Chim. Fr., 25 (1876), 445-451.

223 LE BEL, J.A., "Réponse au mémoire de M. Bourgoin sur l'atomicité comme principe de classification", Bull. Soc. Chim. Fr., 25 (1876), 540-545 (541).

224- BERTHELOT, M., "Atomes et équivalents. Réponse à M. Wurtz", C.R., 84 (1877), 1269-1275 (1274). Note Berthelot's attempt to reduce French chemistry to an unilateral and single form, the école française.

225- WURTZ, A., "Sur la notation atomique. Réponse à M. Berthelot", C.R., 84 (1877), 1349-1351 (1350).

226 TROOST, L.,"Nouvelle méthode pour établir l'équivalent en volumes des substances vaporisables ", C.R., 84 (1877), 711 .

227- At a temperature of 78^0 C Troost had determined the vapour density of hydrate of chloral, which he formulated as $C^4H^4Cl^3O^2.H^2O^2$, a solid substance at room temperature, but which dissociates when vapourised. According to Troost, however, its vapour corresponded to 8 volumes, 4 of anhydrous chloral vapour and 4 of water vapour and he considered that one equivalent of the compound would occupy 44.8 l and its vapour pressure was 117.5mmHg This vapour pressure would be equivalent to the sum of two equal partial pressures corresponding to anhydrous chloral and water vapour, respectively. But it was Troost's contention that there was no water vapour, since he had introduced hydrated potassium oxalate, which by heating dissociates into solid potassium oxalate and water vapour. Its pressure, however would be 53mmHg (78^0C), but in Troost's experiment the hydrated oxalate could not dissociate because if his vapour contained water vapour its corresponding pressure was 58.75mmHg (>53mmHg). The introduction of the oxalate, however causes an increase of vapour pressure of 47mmHg (from 117.5 to 160.5) which is inferior to 53mmHg.

He was taking the equivalent for the gramme-molecule. For his adversaries the interpretation would be that the vapour pressure was the sum of two equal partial pressures (58,75mmHg), that of anhydrous chloral and of water vapour.

228- Troost used this same apparatus.

229- Moreover Wurtz showed that potassium oxalate in the presence of this mixture does not loose water if at the given temperature the pressure of dissociation of the oxalate is equal or inferior to the pressure of water vapour in the dissociated choral hydrate.

230- He argued that according to Gay-Lussac's law, hydrated chloral is composed of 4 volumes of chloral and 4 volumes of water vapour without condensation. Gay-Lussac apparently advocated atoms and gave to his law an atomistic interpretation, but he also showed some ambiguity during his scientific career due to the authoritative opposition of Berthollet. See Rocke, op.cit. (56), p.110-111.

231- WURTZ, A., "Sur la loi des volumes de Gay-Lussac. Réponse à M. H. Sainte-Claire Deville", C.R., 84 (1877), 1183-1189 (1189).

232- DEVILLE, H. S.-C.,"Leçons sur l'affinité" in Leçons de chimie professées devant la Société Chimique 1866 1867 (Paris, 1869), p.13.

233- His own expression. Interesting enough, empires are above kingdoms, thus general mechanics is above chemistry which, despite the different terms, was not in contradiction with current interpretations of Comte's hierarchy of sciences.

234- Ibid., p.15.

235 JACQUES, J. Berthelot. Autopsie d'un mythe, (Paris, 1987), p.77.

236- See Rocke, op.cit. (56), p.181 182.

237- BERTHELOT, M., "Réponse à la note de M. Wurtz, relative à la loi de Avogadro et à la théorie atomique", C.R., 84 (1877), 1189-1195 (1194)

238 Ibid., 1193.

239- Ibid., 1195.

240- Quoted from NYE, M.J. , "Berthelot anti-atomism: a matter of taste?", Ann.Sci., 38 (1981), 585-590 (589).

241 BERTHELOT,M., Essai de statique chimique (Paris, 1879), preface.

242 Berthelot, op.cit. (224),1274.

243 BERTHELOT, M., "Sur la notation de Berzelius", C.R., 84 (1877), 1407-1408.

244- Quoted by Wurtz in op.cit. (225), 1351.

245- See, for instance, BROOKE, J.H., "Organic synthesis and the unification of chemistry - a reappraisal", B.J.H.S., 5 (1971), 363-392 (371-374).

246- Nye, for instance, in op.cit. (240), 590, and Rocke, op.cit. (56), p. 324 argued that both Deville and Berthelot were in the line of the old fashioned tradition of natural history, not of physics. In fact both Deville and Berthelot saw chemistry as a natural science ,but organic chemists like Gerhardt, Laurent, Wurtz and Kekulé were in the tradition of natural history in the sense that they all sought general rules and classification. Furthermore, the models the latter had at their disposal came from natural history, but in its organic and biological sense that emerged in the early century. In addition, both sides aimed at consistency between physics and chemistry. The question is that they did so differently, the main difference being the level of their respective approaches: at the level of the visible (Deville and Berthelot), consequently macroscopic physics became paradigmatic; at the level of the invisible (Gerhardt, Wurtz, etc.) and they sought consistency with microscopic physics.

247- Wurtz, op.cit. (225), 1351.

248 Berthelot , op.cit. (237), 1193.

249- See WURTZ, "Sur la notation atomique. Réponse à M. Berthelot", C.R., 84 (1877), 1264-1268 (1268).

250- As he mentioned

> Je sais parfaitement, quant à moi, que la notion d'atome est une hypothèse, une de celles que l'ont peut faire sur la constitution de la matière, essentiellement lié à une autre hypothèse, celle de l'éther. M. Berthelot la croit mal fondée, par la raison qu'on a jamais vue ni atomes ni molécules. L'argument ne me parait digne de lui. On ne voit pas non plus l'éther.

Wurtz defended his views using the arguments of his adversary, i.e., the invisibility, at the same time he pointed out Berthelot's substantialism, portrayed by his assumption of ether. Ibid.

251- Berthelot, op.cit. (224), 1269.

252- See Chapt. 2, section 3.

253- See Wurtz op.cit. (170), p.448-480, for the articles on atomic theory, and p.1223 for missing entry on the element.

254- For instance Buchanan continued in Paris his work on isethionic acid that he had begun in Kolbe's laboratory. See BUCHANAN, "Sur quelques dérivés de l'acide iséthionique", C.R., 65 (1867), 417-419 (419).

255- Hofmann discovered isonitriles, notably phenyl isonitrile, and his work had been closely preceded by that of Gautier on carbylamines. See Partington, op.cit. (94), p.444. Also Sawitsch's preparation of acetelyne, carried out at Wurtz's laboratory, was simultaneous with that of one of Butlerov's élèves. See JACQUES, J.; BYKOV, G.V., "Deux pionniers de la chimie moderne, Adolphe Wurtz et Alexandre M. Boutlerov, d'après une correspondance inédite", Rev. Hist. Sci., 13 (1960), 115-134 (119).

256- Wurtz, op.cit. (99), 113.

257- Partly alcohol, partly aldehyde.

258- Friedel claimed that

> Si les fruits portés par cette théorie [atomicity] n'ont pas été aussi brilliants en chimie minérale qu'en chimie organique, ils ont permis au moins de grouper les faits d'une manière satisfaisante pour l'esprit et ont substitué à cette simplicité recherchée avec raison à l'origine de la science, et qui consiste dans l'expression plus réduite du fait isolé, une simplicité d'un ordre plus élevé, résultant du groupement d'analogies nombreuses et de l'application de lois générales.

Friedel, op.cit. (210), p.75-76.

259- With this more efficient apparatus Henninger was led to the discovery of glycol in wine.

260- As Gautier said, reproducing Wurtz's words:

> "Prenez garde me disait-il, que la chimie des êtres vivants ne vous fausse la main; c'est une science encore trop imparfaite. Revenez vite à la chimie pure"...Puis quand je lui apportait des résultats précis; lorsque je parvenai à classer les ptomaïnes dans les séries connues...une fois encore il m'approuvait et m'encourageait.

See Gautier, A., et al., "Enseignement des Sciences. Banquet offert à M. le professeur Armand Gautier par ses collègues, amis et élèves", Rev.Sci., 18 (1889), 76-80 (80)..In addition, the Société de Chimie Biologique was only to be created in 1914 .See FOX, R.; WEISZ, G.,(edit.), The organization of science and technology in France 1808 1914, (Cambridge, 1980), p.281.

261- The course which Wurtz gave since 1849, firstly as Dumas's suppléant and afterwards as his successor, was entitled Pharmacy and organic chemistry and was associated before 1874 only with a teaching and research laboratory for organic and inorganic chemistry. See Prevost, op.cit.(4), pp.34-35 and 43-45.

262- WURTZ, A., Traité élémentaire de chimie médicale (Paris, 1864), p.1. His italics.

263- Ibid., p.2.

264- Friedel, op.cit. (1), 70.

265- See Chapter, 2, section 3.

266- WURTZ, A., Traité de chimie biologique, (Paris, 1880),p.1.

267- Ibid., p.2.

268- As Wurtz claimed:

> C'est entre ces deux phases de la création et de la destruction de la matière organique que se déroulent les phénomènes de la vie.

Ibid., p.3.

269- Ibid., p.3.

270- For instance, Pasteur's laboratory at the Ecole Normale was called laboratory of physiological chemistry.

271 Wurtz, op.cit. (266), p.37 .

272- This ferment extracted from papaw was christened papaïne.

273 This exemplifies again the fact of physiological chemistry being the current designation.

274- He was notably a member of the jury of the Universal Exhibition of Vienna (1873) and of all of the same kind which took place in Paris and he presented a Report on the state and economic importance of the artificial dyestuffs industry in a meeting of the Association Française pour l'Avancement des Sciences (1876).

275 At the time Berthelot was president of the Scientific Committee for the defence of Paris.

CHAPTER 5 - FORMS OF COMMUNICATION WITH THE OUTSIDE WORLD: INSTITUTIONAL AND EDITORIAL PRACTICES.

The activity of Wurtz's *école* at an institutional level was widespread and obviously associated with the posts that its members gradually acquired in several areas such as teaching, industry, medical related professions, administration as well as the scientific societies which they joined. Given the long attachment of many of the *élèves* to the *maître* and the affinities of views regarding both ideology and chemical theory which linked them together, their role as individual *savants* cannot be dissociated from the fact they have been trained by Wurtz. This applies particularly to the French, but to a certain extent also to the foreigners, although these had usually a broader experience, involving prior training in other laboratories and contact with different social and cultural environments.

However, as shown before, unlike its French counterparts Wurtz's *école* was part of an international network in which many scientific and cultural concepts were shared, defining a certain kind of pattern. This pattern was related to ideas and practices generated from the Romantic Movement and also to the ideology, especially advocated by the German *Naturphilosophen*. This ideology was propagated into France[1] and the rest of Europe with particular emphasis during the period covering the late 18th century until the 1850s. Despite a high sense of individuality Romantic ideology in its social dimension, embodied the longing to expand one's being into a community, which together with the revival and praise of medieval corporative practices, provided arguments and justifications for the foundation of circles, brotherhoods, associations, international meetings, collective publications at the same time that individual friendships were valued[2]. Thus, from the final years of the previous century emerged many collective initiatives all over Europe and even America, which extended throughout the 19th century.

Wurtz, himself and his *école* were closer to the German version of this tradition in several respects, as shown by their distinct approach to scientific organizations and publications, in the centralised and bourgeois French context[3]. However, this does not mean that in the mid-19th century as indeed before, the practice of these organisations followed strictly the ideological prescriptions as advocated by Romanticism. They obviously acquired regional and national features and incorporated even contradictory ideals, in order to respond as effectively as possible to local practical problems and challenges involving power.

This section is to be focused only on both the institutions and the publications in which the école of Wurtz as a group most strongly enrolled. Particularly the aims and common features involved in the foundation of organisations, which may be divided in two species, scientific and educational, and the creation and editing of scientific publications.

1.- Scientific institutions.

1.1- The Société Chimique de France and the involvement of Wurtz's école.

Despite their different purposes, the foundation of both the Société Chimique de France and the Association Française pour l'Avancement des Sciences corresponded to a second and distinct stage of the cultural phenomena which led to a proliferation of sociétés savantes in France throughout the 19th century[4], in which the Société d'Arcueil, created in the early century, was often invoked as a source of inspiration[5]. In fact, the Société d'Arcueil may be seen as a prototype scientific society in which the members were specialists, but possessed in the Humboldtian[6] sense, a collaborative and cosmopolitan perspective of doing science. But, unlike many of the sociétés savantes of the previous stage, the Société Chimique was to become a permanent organisation of both national and international standing with a well informed and specialised audience

The Société Chimique de Paris (only after 1906 re-named Société Chimique de France) was founded in 1857 by a group of young chemists, who used to gather in weekly informal meetings at a café of the Quartier Latin, with the purpose of discussing their own work and exchanging information about foreign research. In its earliest version the group was mainly composed of foreign chemists attending Parisian laboratories, without the participation of any of their respective maîtres, Dumas, Balard, Deville and Chevreul. The group comprised 12 members, seven of whom were foreigners, and five French including an Alsatian[7]. They elected an administration and approved a set of regulations. Soon, however, those gatherings attracted other young chemists and among them Frappolli, Lieben, Couper, Butlerov, de Clermont and Friedel[8], who while attending Wurtz's laboratory at the Faculty of Medicine also located in the Quartier Latin, socialised in cafés and restaurants of the area. In June of that year and after a preliminary period of discussion on its objectives, in which Butlerov took a lively and active part[9], the Société was formally created by approving its first statutes and by appointing a council, which included Friedel[10] as one of the vice-presidents.

Whereas the other maîtres had no interest in joining the initial group, Wurtz was glad to join the Société (19 May 1858), and together with his élèves, who subsequently followed in a cascade, they soon impressed on the institution a style whose characteristics coincided in many respects with those of his école. Moreover, almost immediately through its publications the Société became an important means of communication between the école and the outside world, by cultivating pluralism of nationalities and of ideas as well as the promotion of national and international exchange of information. Thus, due to the nature of its organisation the Société was to allow a greater openness than was possible for the école alone by enabling the latter to reach a larger audience.

Already with a scientific reputation especially abroad, but most importantly at home recognition by Dumas, Wurtz assumed from the early stages a leadership role within the Société in which, he enrolled many savants with whom he cultivated friendly relationships, revealing simultaneously a deep sense of diplomacy, a knowledge of the local "rules of the game" and an open and collaborative posture, which was not particularly common among his national contemporaries. Thus, as Gautier was to point out, referring to the diplomatic attitude of his maître:

> By inviting his maîtres, his rivals and his friends of the time, such as J.-B. Dumas, Balard, de Sénarmont, Barral, Le Blanc, Sainte-Claire Deville, Cahours, Berthelot, Beilstein and many others, Wurtz transformed from 1858 onwards a group of knowledgeable students into a true learned society.[11]

In 1859, following prescriptions of the French centralised administrative system, the society obtained official approval as a requirement for the sake of its survival and public respectability, and was to adopt the name of Société Chimique de Paris. With this new status, other statutes were approved in which its purpose was defined as being the contribution

> to the advancement and propagation of studies on general and applied chemistry through the publication of memoirs by its members, through prizes and other forms of encouragement.[12]

Also a new administration was elected, which was sufficiently broad to include the notables in the honorary positions: Dumas was the president, Pasteur, Cahours, P. Thenard and Berthelot the vice-presidents. For the working posts, which were to imply responsibility for publication, Wurtz and Le Blanc[13] were elected the secretaries. Friedel and Bouis[14] were the vice-secretaries, Cloëz[15] the treasurer and Perrot, a Swiss élève of Wurtz, was the archivist. The election of notables of the older generation especially for the presidency was maintained in the first 5 years, particularly with the elections of Dumas (1859), Paul Thenard (1861), whose father L. J. Thenard[16] had been a member of the Société d'Arcueil, and Balard (1862). However, in terms of presidencies the situation evolved towards a greater number of elections of the younger generation, and especially of both Wurtz and his élèves. Thus, taking into consideration the Parisian maîtres elected in the first 50 years of the Société, Wurtz,who died in 1884, was elected president three times (1864, 1874, 1878), Pasteur twice (1865, 1869), Deville once (1863) and finally Berthelot, the youngest of all, five times (1866, 1875, 1882, 1889, 1901), which may be seen, especially in the latter case, as a diplomatic measure to prevent possible hostility. When compared, the participation of the élèves of the five major écoles clearly indicates a greater percentage of Wurtz's élèves of both the academic and industrial wings in the presidency. The latter group, however, was less well represented with only three elections: Lauth (1883), Le Bel (1892) and Scheurer-Kestner (1894). Together with the academic wing the presidencies until 1906 amounted to 35%, in which Friedel (1870, 1880, 1888), Grimaux (1881, 1890, 1900) and Gautier (1876, 1891, 1906) won respectively 3 elections each. The percentage of the other écoles was distributed as follows: 4% Deville's élèves, 10% Berthelot's and independents 20%. But, within the latter, were included Schützenberger[17] an Alsatian a devoted friend of Wurtz with 3 elections, as well as Haller (also an Alsatian) and Bouveault[18]. The latter, like others who subsequently follow and belonging to a much younger generation, never attended Wurtz's laboratory but aligned him in Wurtz's tradition as an élève of his élèves .This form of succession by prolonging in time ideas and practices, established a pattern which fitted in the concept of école as a line of continuity in which power was also passed through generations.

However, the participation of Wurtz's élèves in the Société was not confined to the top position of its administration, but extended to other posts, which were as vital for the functioning of the institution as for the success of the école. These were the posts of secretary, treasurer and archivist to which the élèves of Wurtz were regularly appointed. Examples of this are provided by Friedel and E. Caventou ,who held such posts for several consecutive years[19].

As an institution the Société Chimique went through several stages in its relations with the government, after official approval in 1859. Thus, upon its request it obtained the recognition of the state in 1864 when Duruy, at the time Minister of Public Instruction, issued a decree in which the Conseil d'Etat under Napoleon III recognised the Société as an institution of public utility. Although Wurtz was the president at the time, this recognition seems to be rather the result of the series of former presidents considered as notables. This series had begun with Dumas (president in 1859 and permanent president of honour in 1861) and ended with Deville as president in 1863. At the time the former was Minister of Agriculture and Commerce and politically committed to the Emperor and the latter enjoyed the full patronage of his former maître as well as imperial economic support.

With the progressive control acquired by the école of Wurtz, the Société Chimique also underwent a gradual process of decentralisation by opening branches in the main cities in the provinces. In 1884 after Wurtz's death and due to what was considered the growing importance of those branches the Société, at the time under the presidency of Willm, one of his Alsatian élèves, requested permission of the Republican Conseil d'Etat to change its name into Société Chimique de France and to modify the statutes accordingly. A negative reply came in 1885 during the presidency of Schützenberger, giving an idea of the extreme centralisation and power of the French administration regarding the affairs of scientific institutions of this kind. In addition, this incident also hints at the great ideological weight ascribed to the appendage of de

France to a name. Even if with the new name the request of the majority of the members of Société[20] intended to mean more than translating the non-confinement of the institution to Paris, and rather aimed at some sort of national recognition of the impact of the école militante de la théorie atomique[21], surely for the Republican government to legitimate such a claim implied the assumption that the institution was representative of official science and of the country in a nationalist sense. The Société had been until this moment very much under the control of Wurtz's école, a group whose scientific theory was not generally accepted and whose composition was dominated by a social minority of Alsatians and foreigners. Certainly, these were not the requirements to meet entirely the ideological expectations of the Republican and highly nationalist scientific establishment. It was only in 1906, when Gautier[22] was presiding over the Société, that this claim was satisfied, apparently not so much because of the direct request of the branches of Lille, Lyon, Nancy, Toulouse and others, but because the Conseil d'Etat when examining their claim noticed that among the past presidents of the Société were several celebrated savants dear to the national pride[23]. Presumably, among them the name of Berthelot already the Republican symbol of a savant might have played a major part. Indeed if the government of the Second Empire had considered the Société of "public utility" after the symbolic Dumas had been elected its permanent president of honour, now an identical situation occurred since Berthelot received this same accolade in 1900. Despite the different political regime, both cases suggest that the official evaluation of scientific organisms of this kind by the French government was rather based on both the scientific weight and political commitment of their leaders than on the merits or demerits of the institutions.

1.1.1.- Membership.

The members of the Société Chimique, whose maximum membership of 500[24] had been officially imposed since 1859, were initially divided into two broad categories, resident and non-resident members both of which included Frenchmen and foreigners. The members had to pay an annual fee amounting 36 fr.in the first category and 20 fr. in the second, according to the statutes of 1859. In both categories, and almost without exception, Wurtz's élèves entered the Société[25], establishing a close link between attendance at his laboratory and membership in this institution, which extended beyond the period of time they spent in Paris. Also from the early stages of the Société the membership of foreign chemists with whom Wurtz had a friendly relationship and theoretical affinities is striking, and as early as 1861 we can mention the names of his colleagues and promoters of the Karlsruhe meeting Kekulé and Weltzien, the chemist and composer Borodin and the highly regarded Russian senior chemist Zinin.

In 1870, however, the Société recognised that the number of members was not growing as desired, they amounted to only 283, the meetings were poorly attended and also some economic difficulties were pointed out.[26] This situation changed and in the 1880s membership had grown to 400 and by the end of the century it reached 1,000[27]. To this improvement, contributed the creation of two more categories, the permanent subscribers in the 1870s, who paid 400 francs, being entitled to lifelong membership[28], and the membres donateurs in the late 1880s, with the same prerogative as the former upon payment of 1,000 francs. In the second category were included several companies like the railway company of the Midi, the Belgian Solvay Manufactures, several industrialists and among them G. Schaeffer and E. Dollfus from Alsace, F. Kuhlmann from Lorraine, the bank owner d'Eichtal and the publishers Masson and Hachette[29]. Most of them were also to contribute with money to the Association Française pour l'Avancement des Sciences and to the creation of the Ecole Alsacienne. In the remaining categories apart from the chemists either belonging to other écoles or independent, both the presence of members of Alsatian industrial families, chemists technically trained for industry and a significant amount of foreign chemists is striking. The number of the latter, although variable, was relatively high despite the proportion of Wurtz's élèves included. Most of them were Europeans (eastern and western), but there was also a considerable number of Americans often linked to industry.

1.1.2.- The activities of the Société.

In addition to the current three hour meetings taking place twice a month[30] in which the members presented scientific communications, the Société Chimique developed other activities such as public lectures, the establishment of a library, and above all, publications, which the members were entitled to receive upon payment of their membership fee.

After Wurtz joined the Société in 1858 he took the initiative of creating the Répertoire de Chimie Pure of which as secretary he became the chief-editor, and the Répertoire de Chimie Appliquée, whose editor was to be his friend Barreswill. Especially the latter was to play an important role because France lacked journals devoted to applied chemistry with national and international coverage[31] and both journals were intended to analyse French and foreign chemical research. Simultaneously the Société also published its Bulletin in which the papers presented by its members in the meetings appeared in printed form. All the articles were written in French and for this reason translators were part of the editorial board of the three journals, and the first to be appointed were Wurtz's élèves Friedel and de Clermont. This became the common practice in the later versions of these publications, whenever the articles were written in a foreign language.

The first alteration in the patterns of publication occurred in 1862, when the Bulletin incorporated the Répertoire de Chimie Pure and this new version had as members of the editorial board Wurtz, Friedel and E. Kopp, Wurtz's companion of youth in Strasbourg, together with his friends Bouis and F. Le Blanc. As collaborators were elected Riche, Cahours's élève, and Wurtz's élèves G. Carey Foster and Lieben. Also a network of corresponding members of the editorial board was established and its composition is significant : Wurtz's élèves Frappolli (Milan), Luna (Madrid), Lourenço (Lisbon), Sawitsch (Kharkov) and his friends Kekulé (Ghent), Williamson (London) together with the earliest promoters of the Société, Chichkoff (St. Petersburg), Rosing (Christiannia) and Arnaudon (Turin). In 1864 the Répertoire de Chimie Appliquée was also incorporated and from the three former publications resulted a single journal which published not only the papers presented to the Société on pure and applied chemistry, but also other memoirs published in France and abroad. As editors of this renewed version of the Bulletin were Wurtz, his élèves Scheurer-Kestner, Friedel and again F.Le Blanc, Barreswill, Bouis, E. Kopp. As collaborators[32] Wurtz' s élèves Willm, and again Carey Foster and Lieben, together with Riche, Rosing, Thoyot , Vée and A. Girard, the last three whose possible special links are unknown to me. From now onwards the setting was established and the influential part played by Wurtz's école and his close associates on the Bulletin was decisive, at least until the turn of the century, if we take into account that the percentage of the élèves editing the journal corresponded to approximately nearly 50% (1862-1869) and varying from 50% to 75% (1869-1884) of the whole editorial board, excluding both friends and associates with similar chemical views as well as later the élèves of Wurtz's élèves. In the two periods, however, the chief-editors were almost continuously Wurtz or his élèves.

The control over the Bulletin meant also the greatest influence upon the Société as an institution and provided Wurtz's école with the possibility of publicizing both nationally and internationally in the most effective way their research and theoretical views. Simultaneously, it served to reinforce their chemical views in France through the publication of the papers of foreign chemists with a similar approach. Moreover, both the institution and the journal acted as a counter-balance of the power of the rival French écoles of Deville and Berthelot, which dominated the establishment, particularly the teaching system in secondary and higher education .

By becoming le camp retranché de l'atomisme[33] in France, the Bulletin propagated a definite view of chemical theory, which was used by the majority of the authors. A statistical survey carried out in 1869 by Dr. Micé[34] and publicised in 1937 by Delépine revealed that in the pages of the Bulletin of that year 25 foreign and 23 French chemists used a notation based on equivalents, but 191 foreign and 22 French chemists, a half of the latter being trained by Wurtz, adopted atoms[35]. This did not mean, however, that this journal was the only channel for publication at the disposal of Wurtz's école, since articles were regularly published abroad and in the long established French journals Comptes Rendus and Annales de Chimie. Nevertheless, a policy for the promotion of the Bulletin both inside and outside France was launched by Wurtz himself, who in the 1860s published articles exclusively in this journal.

As the above numbers show, although the Bulletin and indeed the Société were dominated by adherents to atomic theory, they were open to everybody regardless of the possibility of opposed ideas. But, the atmosphere which surrounded the young members advocating equivalents was far from being enthusiastic and hence stressed the division between the écoles, as Gautier recognised:

> Without closing its doors to the other sects, the brilliant élèves of Wurtz received almost coldly those who either did not think or write in their way...without abandoning it, many of the members of the Société, whose ideas and language were not adopted by the former, presented their excellent communications elsewhere and the division between the écoles grew[36].

The situation of the students, who at the time moved from the lycées to institutions of higher education and afterwards to chemical research laboratories, very much contributed to this state of affairs, according to Gautier's explanation. They had to change fundamental notions and theoretical concepts depending on the institutions. In the lycées they were taught according to equivalents because the teachers were prepared either in the Sorbonne or at the Ecole Normale where Deville's école dominated. In the Faculty of Pharmacy and the Collège de France power was in the hands of Berthelot and his disciples. Finally, at the Faculty of Medicine the students were taught and trained according to the atomic theory.

Another important activity of the Société for scientific communication and propaganda were the Leçons periodically delivered by both French and foreign lecturers in which the authors were invited to present the history of a particular and original discovery, which was published afterwards in the form of separate booklets[37]. The names of Dumas, Pasteur, Deville, Berthelot, Debray, Wurtz as well as several of his foreign and French élèves and many others guests were associated with these events, which had begun in 1860. However, these Leçons were interrupted during the Franco-Prussian war and for about 14 years they did not take place. The decision to re-introduce them again, this time under the name of Conférences, was the initiative of Lauth, during his time as president in 1883, and their publication in separate volumes was taken by Hanriot (1883-1893).

Adding to the former activities, the decision to found a library of the Société was made as early as 1858 upon a proposal of Barreswill. At the disposal of the members for consultation this library was built up with the French and foreign journals which were subscribed or exchanged with the Société; with the books purchased or presented by the authors to the institution; and with donations such as that of Wurtz's élève Silva who, having systematically participated in the acitivities of the Société notably as president in 1887, made the legacy of his private library to the society when he died in 1889.

For the maintenance and development of all these activities as well of the prizes and encouragement grants, the Société had as sources of income basically the membership subscription, the fees paid by the several categories of members and occasionally donations from benefactors such as Silva and Le Bel or industrialists and companies. However, it went through some financial crisis as mentioned before and in 1894 it almost faced bankruptcy, which prompted Friedel and Scheurer-Kestner to intervene. On this occasion, they used their personal relationships in the industrial and financial world to raise funds, enabling the society to pursue its aims, and when Scheurer-Kestner left his presidency of 1894 the Société was wealthier than ever[38] before.

1.2.- The Association Française pour l'Avancement des Sciences (AFAS)

The AFAS was founded in the aftermath of the Franco-Prussian war (1871) as a reflex of the patriotic feelings which animated the whole country, and particularly Alsace, which despite its German cultural influences claimed its loyalty to France and could not easily accept its annexation to Prussia. The idea of founding such an organisation was thus born in a group of Alsatians, which surrounded Charles Combes, director of the Ecole des Mines, Friedel[39], at the time curator of the mineral collections of that institution, and Wurtz. All the formal founder members, who subsequently joined the group, were said to be

> inspired by the will of contributing to restore the moral of the

country, afflicted by so many misfortunes.[40]

The wish to implement science, the "sovereign of the world"[41] as some claimed, was seen as the solution to prevent further disasters, since the defeat of France was currently attributed by many to the scientific and technological supremacy of Prussia. Therefore, the French authorities were blamed for not having made the required investment in science and technology[42] in the past, and the idea of a certain decline of French science was associated with the recent defeat. Thus, the creation of AFAS was meant to be a nationwide response.

However, under the new political regime, the Third Republic which was generally hostile to the influential position of Roman Catholic Church over French society, the AFAS was not simply a convergence of scientists, industrialists, laymen and women[43] in a post-war crisis. It certainly became also an opportunity for social and religious minorities such as Jews and Protestants, in the past marginalised, to join the mainstream in what was seen as a common national effort, whose intentions were to make up for the alleged past insufficiencies.

Thus, it was under the banner of patriotism that Quatrefages expressed the aim of the AFAS in the motto "à l'oeuvre pour la science et la Patrie"[44], when he delivered his inaugural presidential address in the first meeting at Bordeaux (1872), from which German scientists were excluded under the accusation of having been compromised in the affairs of the war[45]. German science was regarded by the French savants, especially after the Franco-Prussian war, with mixed feelings of admiration and rejection, an attitude which continued to be expressed for the rest of the century[46]. But back in 1872, in the opinion of Quatrefages, as indeed in that of other Parisian academics and army officers of the council of the AFAS, it was time for French science to be "militant"[47], both in peace and war.

Although promoting an initiative of this kind, Wurtz kept his distance from these emotional manifestations of nationalism displayed by some of his Parisian fellow councillors, as his speech in the meeting of Lille (1874) was to demonstrate. As mentioned before, here he openly advocated the ideal of a "New Atlantis" involving all savants world-wide, regardless of nationalities and religious and political beliefs.

Besides his social, political and scientific motivations, it is not surprising for a man like Wurtz to engage actively in an organisation like the AFAS. He was a reader of Oken, and had been educated in the Gymnasium of Strasbourg, which had been precisely the city where at the Congrès Scientifique de France (1842)[48] the German Naturphilosoph had been proclaimed the "father" of scientific meetings[49]. Oken had been a founder of the Gesellschaft Deutscher Naturforscher und Aerzte (created in 1828), which provided a model for similar peripatetic organisations in Europe. However, due to current sensitivities at the time of its foundation Wurtz and the other Alsatian and non Alsatian promoters of the AFAS obviously did not invoke any German ancestry for their organisation. Instead, they said they had modelled their new-born association on its British counterpart, the British Association for the Advancement of Science[50] (BAAS), and Wurtz himself was to choose Francis Bacon[51] (1874) as the philosopher more appropriate to express his beliefs in science as an international and cooperative enterprise involving all sectors of society. In fact, the British model as a source of inspiration for the AFAS was sufficiently innocuous to be perfectly acceptable. Moreover, between 1833-1844[52] Charles Combes had provided together with Dufrénoy, Dumas and others, one of the French connections with the BAAS in whose activities they had participated either as foreign guests at the meetings or as corresponding members. In addition Alsace, the home region of those who most constantly supported the association not so much in words but in practice, had traditionally maintained links with England and Scotland, which extended from religious interests to textiles, dyestuffs and related industries[53]

1.2.1.- Administration of the AFAS and the involvement of Wurtz's école.

In April 1872 the promoters of the AFAS gathered in a meeting in Paris in which a provisional council was nominated. The president was Claude Bernard, replacing C.Combes who meanwhile had died; the secretaries were Wurtz, d'Eichtal, Broca, Quatrefages, Delaunay and Cornu and the treasurer was Masson, a benefactor of the Société Chimique and publisher of its Bulletin. This council decided that the first general meeting of the AFAS would take place in Bordeaux in this same year, and there both a permanent council would be appointed and a constitution approved. Thus, at Bordeaux, Quatrefages was to be appointed president, Wurtz the vice-president, the secretary Levasseur, the vice-secretary Laussedat, the treasurer Masson and the archivist Friedel. They all were members of the Académie des Sciences at the time with the exception of Friedel, Masson and Laussedat, a lieutenant-colonel of engineering.

According to the approved statutes the purpose of the association was to implement pure science and its practical applications through the promotion of meetings, publications, financial support and the supply of equipment to researchers working on projects having the AFAS's approval. The AFAS was to meet for a general eight-day session every year in a different French city, and each year the the proceedings of the meeting (Comptes Rendus de L'Association Française pour l'Avancement des Sciences) would be published including memoirs approved by the AFAS.

During the meetings besides the scientific sessions, the AFAS was to promote other activities, which denoted still some of the Romantic ideals. These activities included guided regional excursions, which embodied the notion of travelling as a process of cultivation through a vivid experience[54], and artistic events such as concerts portraying the ideal of a linkage between science and art. The organisation of these events was to be largely based on the contributions from local administrations as well as learned and philanthropic societies.

As regards its scientific organisation the AFAS was divided into 4 groups[55],which in their turn were divided into sections, chemistry being the 6th section. The involvement of the élèves of Wurtz was almost confined to the "hard-nucleus" and was to occur not only in the 6th section, but also in some top positions in the administration. Thus until 1884, Wurtz was to be involved in the council of the AFAS as vice-president in 1872 and president in 1873; Friedel was appointed archivist between 1872-1876 and vice-president in 1884, and finally Grimaux became respectively vice-secretary in 1882 and secretary in 1883. In the 6th section (chemistry) the presence of élèves varied from one to three between 1872 and 1877 and an average three-four between 1877-1884[56], the total number of members being five. In these calculations associates like Schützenberger and Chancel, a former collaborator of Gerhardt, were excluded.

The participation of Wurtz's école in terms of articles published in the proceedings of the AFAS, under the 6th section (chemistry) was variable and as follows: 33% in 1872-1875 and 1884; 25% in 1877-1878 and 1882; around 15% in 1876, 1879, 1881; between 4% and 9% in 1880 and 1883. Apart from Wurtz, the élèves who contributed articles were William Marcet, Friedel, Crafts, Silva, Gautier, Grimaux, Lauth, Henninger, O. de Coninck, C. Girard, Franchimont, Lecoq de Boisbaudran and, unlike the appointments for administrative positions in the 6th section, the participation in contributing articles was not confined to the "hard-nucleus". In addition, foreign chemists sharing views with Wurtz such as Cannizzaro and Odling also contributed papers to the 6th section .

As regards the number of articles, the contribution from other chefs d'école in the 6th section was almost irrelevant: Pasteur published two articles (1872 and 1875), Berthelot one article in 1872, Deville and Cahours never published. Also in quantitative terms, the number of articles from their respective élèves was insignificant .

1.2.2.- Membership

The members of the AFAS presented a great social heterogeneity, being divided into 3 categories, the founding members, who paid a minimum of 500 fr.subscription, the life members, whose fee was 200fr., and the ordinary members paying 20fr. annually. As far as the élèves of Wurtz were concerned, in the first category were Wurtz, Caventou, C.Girard, the Swiss Perrot, Salet and the Alsatians Friedel, Lauth, and Scheurer-Kestner. In the next category we find the Alsatian E.Risler. Finally, in the third category were Adam, de Clermont, Gautier, Grimaux, Henninger, Pouchet, the Portuguese Silva and the Alsatians Dietz and Willm. Although not members, but rather foreign guests, other former foreign élèves of Wurtz attended the annual meetings[57] either with permission, as prescribed in the statutes, or invitation. As mentioned before, the membership of Wurtz's élèves in the AFAS was in no way comparable to that in the Société Chimique, being almost confined to the "hard-nucleus" of the école.

As regards the other chefs d'école of chemistry, only Pasteur was included in the founders and Berthelot together with Deville were among the ordinary members. It is interesting to note, however, that the Alsatian Jungfleisch, the most direct disciple of Berthelot was, unlike his maître, included in the category of life member.

The membership in the AFAS was not restricted to savants. As mentioned above its compositon was socially heterogeneous, which deserves some attention and may explain why Grimaux claimed that Wurtz and his group were the true founders of the association[58]. In fact, the condition of being Protestant and Alsatian together with the many relations in the industrial and financial world that Wurtz and some of his élèves cultivated were to become extremely important. Friedel, for instance, whose father was a bank owner, together with Lauth and Scheurer-Kestner, who were industrialists involved in administration and politics, favoured the creation of the conditions which attracted members whose professions were linked to economic activities. Furthermore, traditionally in France Protestants and Jews easily associated, not only owing to their condition of social and religious minorities, but also to a kind of economic symbiosis in which the former were usually the industrial entrepreneurs and the latter provided capital. With the conditions created by the deeply anti-clerical Third Republic, these minorities including women saw, at least initially, an opportunity to carve more openly their place in French society. Therefore, among the members of the AFAS we find industrialists in general and more particularly from Alsace such as those belonging to Protestant industrial families like the Dollfus, Engel and Kœchlin; bankers with Jewish surnames or of Protestant denomination like Félix Vernes, with whom Wurtz collaborated in religious initiatives associated with his Church[59], and Alfred André, who was to be also a founder of the Ecole Alsacienne. These, together with several enterprises like railway and metallurgical companies, capitalists like the Baron Rothschild, who also contributed to the establishment of the Ecole Alsacienne, provided a solid financial basis[60], which found no parallel in prior scientific organisations. An example of this was that of Girard, at the time administrator of the state tobacco manufactures at Lyon, who privately donated 200,000fr. to the association. This unusual economic wealth allowed the AFAS throughout the years to award grants for scientific and technical research, through aid for travel, publication and purchase of equipment, especially in the provinces, as well as encouraging the creation of regional learned societies[61]. Also the sociétés savantes already created and operating in several regions, as well as their respective administrators, subscribed to and collaborated with the AFAS.

Among other subscribers to the AFAS some members of the government, like for instance the minister of finance Léon Say or the minister of education Bardoux and military professionals, show how much its creation was closely associated with the political momentum of the time.

Both engineers and academics in general were well -represented including those working in the provinces, but the number of members of the Académie des Sciences was below the expectations. Notably in 1884 at the meeting of Blois, Grimaux commented on this lack of interest revealed by the academician members. However, he added that if the members of the Académie did not join the AFAS, a few members were becoming senior enough to be admitted in the Académie[62]. For the academicians, who were used to communicate their investigations to a professional and elitist scientific audience, the presentation of a paper in a meeting of the AFAS was not regarded as a worthwhile venture. In front of a massive[63] but mostly lay audience the style had to be adapted and the papers were almost written in the form of popularisation articles. In addition, taking into account the highly competitive scientific establishment, the delays in publication of the proceedings of the AFAS did not encourage the communication of original contributions and discoveries, and hence often the academicians did not even bother to attend the meetings[64]. In fact, while the German Gesellshaft Naturforscher followed a decentralised form of academic organisation, such as that which had characterised the German states, and the British Association was grounded on both the British traditional practices of collective initiatives independent from the State, and on a decentralised academic community, in France the situation was radically different. Indeed such an organisation as the AFAS was not well adjusted to the traditions of an academic community whose organisation was well established and concentrated in Paris. To some extent this situation followed the French political and social patterns for administration and social organisation, in which Paris was the obligatory centre, which relegated the provinces to a secondary position and devalued contributions from the periphery.

2.- Educational institutions.

2.1.- The Ecole Alsacienne of Paris.

The project of foundation of the Ecole Alsacienne emerged in 1871 after the annexation of Alsace-Lorraine by Prussia and was seen as a means of resisting colonisation by preserving the Alsatian cultural identity as a part of the chessboard of different regions constituting France. After the Frankfurt Treaty about 150,000 people escaped from Alsace-Lorraine and sought refuge in other provinces and in Paris. These refugees belonged in many cases to a highly educated elite often associated with economic wealth, and were very conscious of their regional culture.

One of the characteristics of the Romantic Movement was to have created throughout Europe the conditions for either regional or national awareness[65], which was expressed and reinforced by growing historical research, by the many recollections of folk tales and songs, by the development of philology as a field, and by the preservation of local dialects[66]. However, this awareness also developed into either aggressive manifestations of nationalism or into forms of patriotism[67], which were open to international cooperation. It is not surprising though, that the Alsatian refugees had to find effective responses to the post-war crisis for the sake of their own preservation as an autonomous culture. In fact, as a part of Prussia they would be subjugated as inhabitants of a conquered land and virtually absorbed due to the similar cultural features they shared with the invaders. Alternatively, by reaffirming Alsace as a part of France in a patriotic but internationalist way, they could more easily avoid social and cultural absorption. In addition, they could take advantage from their cultural differences and habilities to promote themselves as an independent, but highly engaged and committed community of French society. These features together with the opportunities opened by the Republican regime, helped these refugees to participate actively in political, social and cultural commitments.

As a consequence in Paris, a group of Alsatians enjoying considerable social and professional reputation decided to propose the creation of a school where their language, a

German based dialect, their principles and traditional values could be passed on to the younger generation. Among these and the others, who subsequently followed in giving support to this enterprise, were Wurtz and members of the "hard-nucleus" of his école. Consequently, to the extent that an ideal of man was underlying the creation of this primary and secondary school, an analysis of its aims allows us to understand better the essence of the Alsatian ethos. This related not only to Wurtz and his Alsatian élèves, but also attracted non-Alsatian forming the "hard-nucleus", who also enthusiastically adhered to this project. Moreover, some parallels may be established between the ethics and patterns of behaviour which framed Wurtz's école and this institution, showing that they could not be dissociated from the traditions embodied in the cultural roots of its members and associates.

In order to launch the Ecole Alsacienne a manifesto was written by A. Moireau and especially G. Monod[68]. The latter, who was to become member of the council of the school, was a Protestant with Alsatian ancestry and a graduate in History from the Ecole Normale. He had travelled in Italy and Germany, where he established relations with intellectuals and artists such as Nietzsche and Wagner. He was critical towards some French intellectuals, particularly the historians, whom he accused of stagnation. He was to implement in France the historical methods[69] that emerged in Germany from the Romantic movement and was to create the Revue Historique (1875) and the Société Historique (1882)[70]. Thus, it was not surprising that in the manifesto he addressed criticisms to the French traditional educational system, which were subscribed by several Protestant personalities.

On the top of the list of subscribers we found the names of the former governor of the Bank of France Alfred André (also a founder member of the AFAS), who had been elected deputy of Paris in 1871 as a conservative Republican. Following André, were Wurtz, Friedel, de Seynes a professor of the Faculty of Medicine, two engineers A. Parran and L. Sautter, a former member of the Conseil d'Etat, the Baron L. Buissière, the inspector of finances A. Billy, the industrialist Breittmayer and three representatives of the main Protestant Churches, the ministers Dhombre of the Eglise de Paris, Matter of the Eglise Luthérienne and Bersier of the Eglise Libre.

The manifesto denounced and established a demarcation between the aims of the Ecole

Alsacienne and the practices of teaching operating in the official system. Especially the official boarding regime was criticised for the surveillance imposed on pupils; the rigid and punitive discipline; slow methods of teaching based on long written exercises; and the overcrowded classes ran under a military discipline, where the pupils "felt lost in the crowd", being misled in the exploration of their individual capacities and originality[71]. As a private initiative of Protestants, the subscribers of the Ecole Alsacienne also expressed their demarcation from what they considered the unilateral moral order of Jesuit private educational institutions, declaring that their school, despite providing a Christian education, was open to all denominations, by ensuring not only respect, but also adequate spiritual guidance.

Alsace had in the past enjoyed a certain autonomy in its educational schemes and the Ecole Alsacienne was to be based on the principles which governed the Protestant Gymnasium of Strasbourg, founded by the Protestant humanist Jean Sturm[72]. As said before[73], this bilingual school had been created according to the spirit of Reformation and was influenced by German culture. Its syllabus emphasised the learning of a combination of classical culture together with science, mathematics, music and physical education. Its Parisian replica, despite the German occupation of Alsace was to devote particular attention to the teaching of the German language[74], not only for cultural reasons but also, given the situation, as a form of defence. Thus, both French and German cultures were transmitted, through language, literature and philosophy, together with other languages, following the pedagogy of Comenius. In fact the school was also to incorporate, especially through the influence of its first director F.Rieder, the spirit of the Moravian pedagogue of the 17th century, who for longtime had been highly regarded in the German states, particularly by the Romantics, since Comenius's principles for education could easily fit in both the idea of Bildung and in a wholistic approach to nature and knowledge[75]. Accordingly, the Ecole Alsacienne was to practice co-education together with pluralism of religions[76], nationalities[77] and social classes[78]. Moreover, it was claimed that children were taught in a playful manner, being encouraged to contact with nature, to be cooperative and to discover their individual potential[79]. Challenging the most radical prescriptions of positivist ideology and Republicanism, Rieder in his reading of Comenius had claimed, that children's education should be focused on the preparation of the pupils for life and not for science and the aim was to prepare men and not savants or artificial literary vocations. Moreover, the chosen director advocated

> the principles of universality of education, conformity with nature, simultaneous study of things and words, organisation of lessons in the form of a successive, but concentric encyclopedia [80]

With this argument not only the internationalist ideal was reaffirmed, but also an organisation of knowledge that, unlike the positivist, did not imply a linear hierarchy.

The involvement of Wurtz and of the "hard-nucleus" of his école in this institution was carried out at two levels: as administrators, a position which included pedagogic planning, and as shareholders. In 1872 the school was launched as a limited company and among the first shareholders were Wurtz and his élèves, de Clermont, Friedel and Gautier. Later, however, others joined such as Salet, Lauth and Grimaux. The other shareholders were members of industrial Protestant families of Alsace, the Kestner, Kœchlin, Zuber[81], Dollfus, Risler, Schützenberger etc., the industrialists Peugeot, who were family related to de Clermont, and again the bankers F. Vernes and d'Eichtal, as well as the publishers Masson and Hachette and, finally as a benefactor, the Baron Rothschild[82]. Several women were also in the list of shareholders and besides those belonging to the above families of Alsace, were also Miss F. Friedel , Friedel's sister, Mrs. Ferry (born Risler) and wife of Jules Ferry later minister of education and President of the Republic[83] and, Mrs Gide, mother of André Gide, one of the earliest pupils of the school, and others.

The administration, of which Friedel was a member, had the task of not only dealing with the current affairs of the school, but also of putting into practice its pedagogic goals. In this competence it was supported by a committee of studies which established the syllabus and defined the methods. Of this committee de Clermont, Friedel, Gautier, Wurtz and his friend Schützenberger were members. Here, they played an active part, and notably when a discussion took place on the necessary adjustments of curricula in order to fulfil the requirements of the official system to allow pupils to proceed higher education, Wurtz with his suggestions was to reveal again his skills in dealing with the establishment and the rest of society, by avoiding isolation.and preserving at the same time both the pedagogic principles of the institution and its cultural identity[84].

In fact, the Ecole Alsacienne together with the Ecole Monge, in whose foundation Friedel had also taken part, were called écoles libres. To some extent they portrayed the ideal of Lern- und Lehrfreiheit, but in the French context of this period they specifically meant to be schools created as a private initiative, free from government control and from unilateral domination of either religious creeds or political parties. Simultaneously, hostilities were avoided by cultivating sympathetic relationships with members of government and of different religious and political tendencies. In addition, a constant re-affirmation of Alsatian patriotism and commitment to France was a vivid and permanent concern, which had been expressed in the motto Pro scientia et patria since the manifesto launching the Ecole Alsacienne .

The Ecole Alsacienne was to become a successful enterprise, exchanging experiences with other schools in England, Russia, Switzerland, Germany etc., which were especially developed after its presence in the Universal Exhibition of Paris in 1878. Particularly in France it became in many respects a model, even for university-level education, and inspired further reforms in the official teaching system[85].

2.2.- The Ecole Municipale de Physique et de Chimie Industrielles.

The foundation of the Ecole Municipale de Physique et de Chimie Industrielles provides a mutation as regards the professionalisation of chemists in France. In fact, it emerged as the first institution in which chemists or physicists were officially and specifically taught and trained as such. Furthermore, in itself this school portrayed a response to the traditional second rate position ascribed in practice and in many instances to applied science, despite the speeches praising the importance of application in industry and agriculture as a source of economic wealth.

Looking back at the recent past which preceded the foundation of this school, two sorts of situation may be found. First those who became professional chemists usually obtained their higher education at institutions where chemistry was taught simply as a discipline and consequently the main aim at a graduation was not chemistry itself. Therefore, the usual backgrounds of established chemists could be found in medicine as in the cases of Wurtz and Deville, pharmacy like Dumas, Berthelot or Haller, a degree in science from the Sorbonne like Friedel or a graduation from the Ecole Polytechnique like Le Bel. With these backgrounds the candidates to professional chemistry were afterwards trained in a research laboratory supervised by a prestigious maître like Liebig, Dumas or their successors, in which they were initiated in research. In France, as mentioned before, these research laboratories had been organised within official institutions, but on the basis of some sort of private arrangement. After this training period the chemist candidates would either engage in an academic career helped by the patronage system or, alternatively and less often, they would have a more technical career in some state department or as industrial or agricultural chemists.

At a lower level was the laboratory of Frémy at the Muséum d'Histoire Naturelle, where préparateurs were trained strictly on chemistry. No qualifications of any kind were required for admission and, as said before, together with the fact that no theoretical framework was advocated and research was outside its scope this was not considered an école, but merely a place where current practices of laboratory routine were taught. The chemists trained by Frémy later worked mainly as préparateurs and only a few engaged in research by entering one of the existing écoles. His laboratory closed down in 1892 owing to alleged mis-management, which was enhanced by the hostility of Berthelot towards Frémy[86], creating something of a gap as regards the training of technicians. The only exception to this general picture was the Ecole Supérieure de Chimie de la Ville de Mulhouse in Alsace, created as early as 1822 due to the initiative of regional industrialists[87], but its aims were very much confined to the local interests associated with textile industry.

The Ecole Municipale was thus to provide a distinct professional training when compared with the preceding schemes. In its creation a new status for applied science was implied, since the technical dimension of chemistry was not reduced to a set of mechanical laboratory operations with an almost complete disregard of theory as in the case of Frémy. Instead, a close association between science and technology became central. Here, the students received both theoretical instruction and laboratory training on equal footing, as the école of Wurtz advocated, with the specific purpose of becoming professional physicists or chemists, and were technically prepared to perform, develop and interpret chemical operations, wherever their skills were required.

The first step towards the creation of the Ecole Municipale de Physique et de Chimie Industrielles was given by Lauth, an élève of both Gerhardt and Wurtz, as the result of a report he addressed to the Minister of Commerce, after his appointment as rapporteur of the Class of chemicals in the Universal Exhibition of 1878. Lauth had already an established prestige: he had made a name for himself in the city council, the Conseil Municipal de Paris (1871-1880)[88], where he introduced several innovative measures regarding education and hygiene; as a chemist he had contributed to the replacement of the traditional colours extracted from an animal or vegetable source[89] by synthetic dyestuffs, whose preparation had been made possible in the framework of a chemical theory; and finally he was also a successful manufacturer, as director of the manufactures of Sèvres.

In his report Lauth argued that the French chemical industry was inferior to its foreign competitors, and he requested the minister some measures, especially the creation of a national school to prepare professional chemists. For this purpose he enclosed a plan of a three year course, comprising theory and laboratory practice. This claim, however, had no official response, but Lauth sought the support of some of his friends in the Conseil Municipal. These were the publisher Germer-Baillière, Bixio the president of the administration of the Compagnie des Voitures de Paris and Lanessan, who was to become Navy Minister. These produced a project in 1880, which differed from that of Lauth only because it also included physics. This project obtained the approval of the local administration and the Prefect of the Seine department appointed an administrative committee. This committee included Wurtz and Lauth, Berthelot, some members of the Conseil Municipal and others, who were also active members of the AFAS like Gariel, engineer of Ponts et Chaussées, and the polytechnicien Bréguet, a former colleague of Wurtz at the Société Philomatique. The school was opened in 1882 and the director appointed was Schützenberger (1882-1897)[90]. Among the appointed staff[91] were Wurtz's élèves Henninger, Silva, and Etard, who together with Schützenberger were in charge of the chemical courses. The directorship of the Ecole Municipale was to be for several years in the hands of Alsatians, which to some extent denotes the open way in which applied science was differently valued in the Protestant and German influenced cultural context of Alsace. Thus, after the first director, Schützenberger came Gariel[92] in 1897, then was Lauth (1898-1905), and finally Haller[93] (1905-1925). At first and for several years, these directors had to face, especially in the discussions on budget, lack of understanding by the authorities, who could not make sense of the necessity for such a technical school[94]. The recognition of its standards as those of a higher education institution came only in 1926[95] and materialised in the incorporation of the Ecole Municipale in the Faculty of Sciences of the University of Paris (Sorbonne), in accordance with the usual centralisation practices.

3.- Publications: journals, articles, dictionaries and textbooks.

In addition to the editorial responsibilities associated with the publication of the Bulletin de la Société Chimique de France the école of Wurtz also engaged in other collective publications such as Wurtz's dictionary and the Agenda du Chimiste. The Dictionnaire de chimie pure et appliquée was published by Hachette publishing company, which as mentioned before was a shareholder of the Ecole Alsacienne, subscriber of the AFAS and publisher of its proceedings.

The contents of Wurtz's Dictionnaire were organised in alphabetical order, comprising organic and inorganic chemistry, chemistry applied to industry, agriculture and crafts, analytical chemistry, physical chemistry and mineralogy. This multi-volume work was first published in three volumes in five parts between 1869-1878, subsequently followed by supplements between 1880-1886, 1892-1901 and 1906-1908. The élèves who took part in the editorship were not only those of the "hard nucleus"[96] but others, who often were also co-editors of the Bulletin., like for instance the Swedish Clève. The same applied to associates such as Schützenberger, Bouis, E. Kopp, Le Blanc, Dehérain etc.. In addition, in the first three volumes members of other écoles also participated such as Deville's élèves Troost and Hautefeuille, but they ceased their collaboration in the subsequent supplements, presumably due to the controversy which took place in the Académie des Sciences in 1877, between defenders of atoms and of equivalents. Between 1892-1901 there was no specification of chief-editor and the number of editors of the Dictionnaire increased considerably, including élèves of

Wurtz's élèves. Finally, between 1906-1908 the dictionary had two chief-editors Friedel and Chabrié and as in the previous case the collaborating editors included a few former élèves of Berthelot such as Maquenne and Delépine. Throughout the years, although without any editorial status, several élèves of Wurtz contributed articles to this publication.

If the Dictionnaire had been an idea of Wurtz which had the collaboration of his élèves, the Agenda du chimiste was to be the other way around. It was first published in 1876 also by Hachette, and its founder editor was Wurtz's élève Salet, who was particularly fond of his maître[97]. The Agenda was intended to be used by engineers, physicists, chemists, chemical manufacturers, agriculturalists, sugar manufacturers and in dyeing industry. Immediately after its publication the Agenda penetrated the laboratories and factories and its usage became widespread both in France and abroad. According to its creator, Salet

> At the beginning it was a manuscript book, which was constantly consulted by Wurtz's élèves in the laboratory. The idea of making a brochure of a portable format and accessible price came to me and Henninger helped to revise it and complete the main sections. Then Girard and Pabst, who were at the same time preparing a more technical Agenda[98], whose necessity had been pointed out by several industrial associations and especially by that of Mulhouse, joined their material to ours.[99]

Wurtz promptly encouraged this project and wrote a preface which, after his death[100], continued to be printed at the beginning of each issue of the Agenda. He notably praised the collective nature of the booklet [101] as well as its practical character.

The Agenda comprised information and the data collected from articles scattered through several journals. These were condensed in tables and the description of methods and procedures was presented in an economic manner. It comprised three chapters and the first dealt with aspects relating to physics and mathematics such as conversion of weights and measurements, coefficients of expansion, vapour densities, densities, melting and boiling points, refraction indexes and rotatory powers, etc.. The second chapter was devoted to pure chemistry, and provided lists of simple bodies and their symbols, atomic weights and equivalents, specific heats, solubilities in different solvents and their variation with temperature, etc.. It also provided information on qualitative and quantitative analysis, as well as on spectroscopic analysis, after all Salet's specialty. Finally the third chapter concerned applied chemistry, and described technical procedures and methods such as alloys analysis, analysis of water, wine, and milk etc. Also industrial techniques for glass, ceramic, dyestuffs and explosives industry etc.were given. In addition, and throughout the three chapters, chemicals, instruments and apparatus were advertised, which presumably may have played an important role in minimising the costs involved in publication.

This prototype of a laboratory handbook also contained a supplement where articles considered of general interest were presented. These could be on topics like rabies by Pasteur[102] or about calculations involved in analysis of mineral water by Willm[103]. Occasionally biographies of scientists and their contributions were also included. Besides the former editors several élèves of Wurtz collaborated both with articles or in the revision and actualisation of tables, parameters, methods and procedures. Among them we may mention Griner, Lauth, Willm, A. Combes and others.

Apart from these collective publications we may also consider as a collective enterprise the regular publication of the articles produced by the école. Besides the journals already mentioned, the Comptes Rendus, the Annales de chimie[104] where Wurtz had some influence, first as reviewer of foreign research (1853-1867) and afterwards as editor, together with the Bulletin, which was controlled by his école, a considerable number of foreign journals was also used as channels for publication. These were mainly German, such as the Liebig Annalen and the Erdm. Journ. Prak. Chem., in which both Wurtz and his élèves regularly published. Occasionally also the Italian Nuovo Cimento, as well as English and American journals together with those from the countries of origin of the foreigners attending Wurtz's laboratory were also used for publication. However, despite the great amount of articles published by the école as a whole, as regards Wurtz himself, the number of papers he published was not considered very high, according to his contemporary standards[105]. Especially, when compared with the extraordinary quantity of articles published by Berthelot, who often published memoirs which were variations of a same article already published time and again[106]. These practices were consistent with an ideology, which praised quantity and detail, as a criterion of scientific integrity and truth (Berthelot) as opposed to that which valued economy and simplicity (Wurtz).

In addition to the textbooks published by Wurtz himself, his élèves of the "hard-nucleus" also published individually textbooks focusing on different aspects of chemistry[107]. Due, on the one hand, to their lifelong attachment and, on the other, to the common and general theoretical grounds shared by the authors, to some extent, they may be considered as a product of the école, in its assertion of sharing a système. Despite that common basis[108], allowances were made for personal interpretations and different formulation of chemical questions from those put forward by the maître. However, they do not seem to have had any interference in their esprit de corps, if we judge by their mutual reviews of books in journals like the Revue Scientifique or when Wurtz acknowledged and discussed original interpretations provided by his élèves[109].

NOTES TO CHAPTER 5.

1- Both for those German Romantics fully engaged in the movement and those who despite assuming critical attitudes were clearly a product of its ideology, Paris was a pole of a special attraction, and as examples we may point out Schlegel, A. Humboldt and Heine. For instance, it was while in Paris that Heine, who despite being a Romantic assumed a critical posture, wrote Die Romantische Schule (1832) in which he expressed his satirical criticism of personalities and ideas of the Romantic period.See CARDINAL, R., German Romantics, (London, 1975), p.22. See also SCHENK, H.G., The mind of the European Romantics (London, 1966) and BRUFORD, W.H., The German tradition of self-cultivation. 'Bildung' from Humboldt to Thomas Mann, (Cambridge, 1975).

2- See Cardinal, op.cit. (1), p.28 and Schenk, op.cit. (1), chapt.15 and 16.

3- FOX, R.; WEISZ, G., (edit.), The organization of science and technology in France 1808-1914, (Cambridge, 1980), pp.270-271.

4- Ibid., p.244.

5- See CROSLAND, M., The Society of Arcueil: a view of French science at the time of Napoleon I, (London, 1967).
Notably André, a former élève of Berthelot, in a ceremony which took place in Strasbourg (1921).to honour Wurtz, mentioned the role of the Society of Arcueil as a source of inspiration.See PAQUOT, C., Histoire et développement de la Société chimique depuis sa fondation, (Paris, 1950), p. 4.

6- A. Humboldt was himself a member of the Society of Arcueil. See Crosland, op.cit.(5).

7 The members were:

Committee members

Arnaudon (Italian), élève of Chevreul, Gobelins Manufactures.
Collinet (French), élève of Dumas, Dumas's private laboratory.
Gensoul (French), élève of Deville, Sorbonne.

Ordinary members

Chichkoff (Russian), élève of Dumas, Dumas's private laboratory.
Rosing (Norwegian), élève of Dumas, Dumas's private laboratory.
Ubaldini (Romanian), élève of Balard, Collège de France.
Bauvallet (French), préparateur of G. Ville, Muséum d'Histoire Naturelle.
Laureau (French), élève of Riche, Sorbonne.
Mantas, (Portuguese), élève of Chevreul, Gobelins Manufactures.
Meyer, (French, Alsatian), élève of Deville, Sorbonne.
Salazar, (Latin American), élève of Cloëz, Muséum.
Pavesi, (Italian), élève of Deville, Ecole Normale.
See Paquot, op.cit. (5), p.3.

8 GAUTIER, A. "Le cinquantenaire de la Société chimique de France", Rev. Sci., 7 (1907), 641-689 (643).This article is also included in the book Centenaire de la Société chimique de France (1857-1957), (Paris, 1957).

9- JACQUES, J.; "Boutlerov, Couper et la Société chimique de Paris", Bull. Soc. Fr., 20 (1953), 528-530.

10- The presidents were Rosing (1st semester of 1858) and the industrial chemist Aimé Girard (2nd semester of 1858). The vice presidents Friedel and Riche.See Statutes in Bulletin des scéances de la Société chimique de Paris, (1858 1860).

11 Gautier, op.cit. (8), 646.

12 Statutes in Bull. Soc. Chim. Paris (1859), 65-71 (65)

13 Like Wurtz, F. Le Blanc had been élève of Dumas.He was friend of Wurtz and also collaborated in his

dictionary.

14- Bouis and Wurtz established their friendship in Dumas's private laboratory.

15- Cloëz was the director of Chevreul's laboratory in the Muséum. He was friend of Wurtz and he collaborated and published joint papers with Cannizzaro (1851), who had a special admiration for the Alsatian chemists Gerhardt, Wurtz, Friedel and Schützenberger.

16- Baron L.Thenard had died in 1857, which may explain this election. In the biographies of the presidents of the Société the only comment that Gautier made on the Baron's son was:

P.Thenard qui succédait à Pasteur et qui avait hérité du grand nom de son père.

Gautier, op.cit. (8), 645.

17- Like Wurtz he had been a student and préparateur of Prof. Cailliot at the Université de Strasbourg.

18- Bouveault was an élève of Hanriot, an élève of Wurtz.

19- See Appendix 1, Table II.

20- The percentage of votes in favour of this proposal was 75%. Paquot, op.cit. (5), p.4.

21- Gautier in his presidential address in 1906. Quoted from Paquot, ibid., p.3.

22- Gautier was politically committed to the Republican party and as far as politics were concerned ideologically close to Berthelot.

23- See Paquot, op.cit. (5), p.5.

24- In addition to these members the Société was allowed by the authorities to nominate 20 honorary members. See op.cit.(12), 65.

25- See Appendix 1, Table II.

26- See THIERCELIN, L., et al., "Rapport sur les comptes du trésorier pour l'exercice 1869", Bull. Soc. Chim. Fr., 13 (1870), 9-10.

27- Fox, op.cit. (3), p. 272.

28 Wurtz and his élèves Caventou, Friedel, Scheurer-Kestner, Grosheintz, Lauth, etc., but also Berthelot were in this new category.

29- The Bulletin was published by Masson publishing company.

30 According to the statutes of 1859.

31- See Fox, op.cit.(3), p.271.

32- The distinction between collaborators and corresponding collaborators, in addition to the editors, was replaced by editors and collaborators.

33- Gautier's expression in Paquot, op.cit. (5), p.3.

34- Professor of the Faculty of Medicine of Bordeaux.

35 METZ, A. "La notation atomique et la théorie atomique en France à la fin du XIX^{e} siècle", Rev. d'Hist. Sci., 15 (1963), 233-239 (fn., 235).

36- Gautier, quoted from Paquot, op.cit. (5), p.3.

37 Until 1900.

38- Gautier, op.cit. (8), 654. These donations amounted 180,000fr. in the 1880s-1890s and among them that of the Solvay company in 1894 amounted 10,000fr. See Fox, op.cit. (3),fn.p.272.

39- Through his second marriage Friedel was to become Combes's son-in-law.

40-CORNU, A.,"Histoire de l'Association Française", Ass.Fr. Av. Sc. C.R., 1 (1872), 44-49 (44). Cornu was Secretary general of the AFAS (1872) and professor at the Ecole Polytechnique.

41- QUATREFAGES, A., "La Sciences et la Patrie", Ass.Fr. Av. Sc. C.R., 1 (1872), 36-41 (39). Quatrefages was a physiologist, anthropologist and president of the AFAS (1872).

42- Quatrefages, ibid., 37. As further examples of this spirit see PASTEUR, L.,"Pourquoi la France n'a pas trouvé d' hommes supérieurs au moment du péril", Rev. Sci., 4 (1871),73-76. See also PAUL, H., The sorcerer's apprentice. The French scientist's image of German science 1840-1919 (Gainsville, 1972).

43- An interesting and innovating feature is the presence of few women as founder members of the AFAS, such as Miss Combes, daughter of Charles Combes and later Friedel's second wife and Mrs.A. Dollfus from Alsace, or Mrs. Gariel (life member), wife of the Alsatian Gariel (see fn.92) The Alsatians seem to have been in favour of women's participation in society as illustrated by Wurtz when, while Dean of the Faculty of Medicine, he admitted female students. The Alsatian tradition of men taking the wife's surname (a matriarchical feature) reinforced by Comenius views on education, which were popular among many Alsatians may have contributed to this attitude.

44- Cornu, op.cit.(40),48.

45- Quatrefages, op.cit. (41), 39.

46 For instance in 1916, during World War I, the academician E. Picard, speaking of the "dangers" of German Science, said:

> There must be a reform in the conduct of international congresses. They have become the springboard of Germanisme. It is to be hoped that we shall succeed in arranging with our allies and friends congresses from which Germany will be excluded: because of her barbarism she had placed herself beyond the circuit of civilised nations.

Quoted from COLEMAN, W. (edit), French views of German science, (N.York, 1981). This book is a compilation of extracts from LOTE, R. Les origines mystiques de la science allemande, (Paris, 1913); PICARD, E., L'histoire des sciences et les prétentions de la science allemande, (Paris, 1916), both anti-Germanic accounts, and WURTZ, Les hautes études pratiques dans les universités allemandes, (Paris, 1870 and 1880), which presents German laboratories and scientific organisation as a model to be followed to a great extent.

47 Quatrefages, op.cit. (41), 41.

48- Fox, op.cit. (3), p.272, drew attention to some resemblances between the AFAS and two previous French peripatetic organisations, the Congrès Scientifique and the Association Scientifique de France.They declined with the foundation of the AFAS and Wurtz entered into negotiations in order to amalgamate the latter, which had been established by Leverrier in 1864. See GRIMAUX, E., "L'Association française 1883-1884", Rev. Sci., 34 (1884), 293-296 (294).

49 See KLEIN, M., Article Oken, D. S. B., vol. 10, pp.194-196 (195).

50 In the arguments used, which were particularly optimistic, the BAAS was presented as a miraculous means of conversion, given the peculiar image that Quatrefages had of the British :

> Grâce à elle (BAAS) une partie de la population a été transformée. Les fils de ces chasseurs de renard, qui, pour se délasser de leurs rudes passe-temps, ne connaissaient que des joies, également violentes et matérielles, sont aujourd'hui des botanistes, des géologues, des physiciens, des archéologues.

See Quatrefages, op.cit. (41), 40.

51- See Chap. 2, p. of this thesis.

52 See MORRELL, J.; THACKRAY, A. , Gentlemen of science. Early years of the British Association for the Advancement of Science, (Oxford, 1982), pp.375 384.

53- See Chap. 2, p. of this thesis.

54- This same idea was to be applied as a teaching method for children at the Ecole Alsacienne. See the excursions instructives in HACQUARD, G., Histoire d'une institution française: l'Ecole Alsacienne. Naissance d'une école libre 1871-1891, (Paris, 1982), vol.1, pp.94.

55- The groups were organised following Comte's classification of sciences (between the 1st and the 3d), but applied sciences were included as sections:

1st Group Mathematical Sciences
1st section. Mathematics, Astronomy and Geodesy.
2nd section. Mechanics.
3d section. Navigation.
4th section. Military and civil engineering.
2nd Group Physical and Chemical Sciences
5th section. Physics.
6th section. Chemistry.
7th section. Meteorology and physics of the globe.
3d Group Natural Sciences
8th section. Geology and mineralogy.
9th section. Botany.
10th section. Zoology and zootechnics.
11th section. Anthropology.
12th section. Medical sciences.
4th group Economy
13th section. Agronomy.
14th section. Geography.
15th section. Economy and statistics.

56 See Ass.Fr. Av. Sc. C.R.,between 1872 1884.

57 See Appendix 1, Table II.

58 See Grimaux, op.cit. (48), 294.

59 See FRIEDEL, C., "Notice sur la vie et les travaux de Charles-Adolphe Wurtz", Bull.Soc Chim. Fr., 43 1885), 1 80 (24).

60 In the 1870s the capital of the AFAS was more than 300,000fr. and by 1914 was about 2,000,000fr. See Fox, op.cit. (3), p.274.

61 Notably the Société de Géographie Commerciale de Bordeaux was created as a result of the meeting of the AFAS in 1872. Fox, ibid..

62 Grimaux, op.cit. (48), 295.

63 In 1880 the AFAS meeting had an attendance amounting to 712 people from a membership of 3,156 and in the 1890s membership reached about 4,000 subscribers. See Fox, op.cit. (3),p.274.

64 Ibid.

65 The Romantic attitude rejected the idea of a universal society which could make all nations uniform, instead it emphasised national peculiarities. See Schenk, op.cit. (1), p.15.

66 Ibid., p.17.

67 According to the distinction given by Schenk, patriotism is different from nationalism: the former

corresponds to a sentiment of attachment and the second to a feeling of pride often leading to arrogance. Ibid.

68 G. Monod was considered an important figure of French Protestantism and, like Wurtz, only after obtaining international recognition in his case due to studies on history and philology he was to become a member of the Académie des Sciences in 1897.

69 Romantic historiography focused more on what men have thought.

70 See Hacquard, op.cit (54), p.4.

71- Notably Rieder, the first director of the Ecole Alsacienne once in a letter addressed to his parents mentioned that

> Il n'y a qu'une manière de réussir dans le monde, c'est d'y apporter sa part d'originalité, quelque petite que puisse être cette part.

Quoted from Hacquard, op.cit.(54), p.21.

72 See Chapt. 2, fn. 36, p. 102.

73 See Chapt. 2, section 2.1.

74- German language was taught from the first form of primary education until the end of the secondary studies. The later forms studied German philosophers and writers as well as French.

75 See AARSLEFF, H., Article Comenius, D.S.B., vol.3, 359-363.

76 The pluralism of religions as practiced in the school was particularly praised by the priest of Saint- Sulpice as regards Catholicism .Moreover it had the support of and was attended by the children of this heterogeneous group of usagers de l'école:

> Monod, un des grands noms du protestantisme français; le docteur Charcot, qui se déclarait bouddhiste; Michel Bréhal, israélite de marque; le général Brocher, ami personel de Mac-Mahon, orléaniste et catholique.

Saint Etienne, quoted from Hacquard, op.cit. (54), p.149 and also pp.147-150 for other testimonies of religious freedom at the school.

77 From the early stages of the school, American and Russian children were among the pupils.

78 See Hacquard, op.cit. (54), pp.41 and 65.

79 Ibid., pp.24-26.

80 Ibid. p.26.

81 The Zuber were a very influential Alsatian family from the cultural point of view. See Chapt 1 of this thesis. Notably the painter Henri Zuber, whose son was to attend the Ecole Alsacienne, occasionally advised the school in artistic matters such as drawing.

82 The Baron of Rothschild made a donation of 500fr. See Hacquard, op.cit. (66),p.41.

83 He advocated a lay teaching system as a reaction to Pius IX Syllabus (1864), in which he claimed for the Catholic Church the exclusive privilege on educational matters. As a Republican he condemned chauvinism and extreme nationalism which, in his view, would lead France to isolation.

84 See Hacquard, op.cit. (54), p.64.

85 Ibid., pp. 144 145 and 186 187.

86 COPAUX, H., (edit.), Cinquante annés de science appliquée `a l'industrie 1882 1932, (Paris, 1932), p.11.

87 See FOX, R. "Presidential address: science and social order in Mulhouse, 1798 1871", B.J.H.S., 17 (1984), 127 168 (150).

88- See Appendix 1, Table IV, and Chapt.3. See also HANRIOT, M., Announcement of Lauth's death, Bull. Soc. Chim. Fr., 15 (1814), 77 79 and HALLER, A., "Notice sur la vie et les travaux de Charles Lauth", Bull.Soc. Chim. Fr., 21 (1917), 1 14.

89 Notably, Lauth had synthesized violet of Paris in 1866, followed by green methyl and blue methylene.

90- Schützenberger had taught at the Ecole Supérieure de Chimie de la Ville de Mulhouse.

91 Pierre Curie as member of staff was together with Marie to carry out their research on radioactivity in the laboratories of this school.

92 Gariel was engineer of Ponts et Chaussées and he lectured both on physics at the Ecole des Ponts et Chaussées and hygiene at the Faculty of Medicine. Since its foundation and for about 30 years he was secretary of the AFAS. Like Wurtz and G. Monod, he had also a reputation as a musician.

93 Haller was professor of organic chemistry at the Sorbonne and was the founder of the Institute of chemistry at Nancy (1890).

94- See op. cit. (82), p.37.

95 Ibid., p.47.

96- See Appendix 1, Table III.

97 See FRIEDEL, C., "Notice sur la vie et les travaux de Georges Salet", Bull.Soc.Chim. Fr., 12 (1894), 17-32.

98 His italics.

99 Preface by Salet, Agenda du Chimiste (Paris, 1878).

100 Notably, Salet praised Wurtz 's patronage, which explains the maintenance of the Wurtz's preface of 1877. In Salet' s own words:

> Celui sous le patronage duquel cet opuscule s'est présenté pour la première fois n'est plus là pour nous encourager.

Preface, Agenda du Chimiste, (Paris 1886).

101 Wurtz mentioned:

> C'est une œuvre collective dont les auteurs ont voulu garder l'anonyme; ils sont déjà connus du public scientifique, et celui qui écrit ces lignes les a vu, depuis des années, d'abord s'exercer et se former, puis prendre leur essor et s'élever autour de lui.

Preface, Agenda du Chimiste, (Paris 1877).

102 PASTEUR, L., "Sur la rage", in Agenda du chimiste, (Paris, 1886).

103 WILLM, E., "Sur le calcul de l'analyse des eaux minérales", in Agenda du Chimiste, (Paris, 1886).

104- The articles published in the Comptes Rendus were often published also in the Annales de Chimie , which allowed an extended version in which experimental details could be given. Usually these appeared much later.

105 Wurtz published about 140 articles. See Friedel, op.cit. (59)

106 See Berthelot's dispute with Wurtz about publication in the Annales de Chimie in Chapt. 3, section 2.3.

107 See Appendix 1 , Tables V and VI.

108 I am deliberately excluding the case of Couper, who undoubtedly denied the value of Gerhardt's type theory and consequently Wurtz's theoretical framework. Couper clearly proposed a radically different approach.

109 See, for instance, WURTZ, "Histoire générale des glycols", in Leçons de chimie professées devant la Société Chimique de Paris (Paris, 1860).

CONCLUSION.

In deriving conclusions from this thesis three major aspects will be focused on: the methodology applied, the consideration of Romanticism and finally, the importance of Wurtz's school in the context of the period.

In the course of my investigations I arrived at the conclusion that if I followed strictly the patterns of previous studies on research schools many peculiarities of Wurtz's school would be left out or without apparent explanation. Consequently, I was led to approach the subject from three major points: the *maître*, the *élèves* and the *école*. These three categories emerged from the contact with the historical sources and were determined in accordance with the corresponding concepts of this period of history.

Thus, the consideration of the meaning of a *maître* with all the implications associated with that position in the French 19th century context allowed us to understand: the type of charismatic features involved; the structure of power in the hands of the *chefs d'école* of chemistry and the rules of their *modus vivendi* as well as of those who surrounded them; the power and forms of control used, which included patronage for posts, publication and even involvement in personal matters of the private life of their *élèves*; and finally the expectations of those who practically had to place themselves under the protection of a *maître* in order to follow a scientific career.

The consideration of the meaning of *élève*, on the other hand, avoided as much as possible the interference of subjective factors. Particularly an analysis which might have lead us to consider only the *élèves* mentioned in the available records and, among them, select those who had been "true research students", a category defined as for instance by: a)those who were young b) those who were not yet committed to a particular chemical theory c) those who exclusively attended Wurtz's laboratory merely aiming at learning how to do experiments for only practical reasons. An approach of this type would inevitably have resulted in the dismissal of some cases of Wurtz's *élèves*, such as those of the young Couper and the old Lecoq de Boisbaudran, who shared the fact of having well grounded personal ideas before attending Wurtz's laboratory. We would be probably rejecting also those who, prior to Wurtz's laboratory, attended other laboratories, such as that of Gerhardt (Lauth), Cahours (Etard, Demarçay) or German laboratories, ignoring in this way important factors. Instead, the study of the contextual meaning of being an élève of a maître provided an alternative, which allowed us to consider the whole spectrum of possibilities of becoming a member of an école as it was understood in this historical period.

Finally, the cultural meaning of école as a typical phenomenon of the 19th century, led us to understand that the école was not confined to science, but affected other areas such as art, literature, music and philosophy and, in France, clearly as a form of indoctrinating younger generations and maintaining the status quo. In the case of chemistry the école, therefore, was not restricted to laboratory training in a specific area of chemical research, but was subordinated to a "doctrine" or système. The idea of a système underlying the école was a requirement inasmuch as a defined theoretical framework in chemical research was indispensable for the definition and identity of an école in this period. In addition, it also showed how the école embodied social and scientific practices which were not confined to the laboratory, but implied a posture in relation to the outside world. At the same time the école was strongly infused by moral and ideological aspects that the maître was also supposed to transmit and the élèves absorb. In conclusion we may say that this framework intrinsically entails the description of the cultural and sociological context in which an école was located.

In the existing studies of research schools of chemistry of the 19th century the influence of Romanticism is not recognised, neither in chemistry nor in the organisation of research. However, the consideration of some trends generated from the Romantic Movement and German Naturphilosophie emerged as a necessity imposed by the characteristics of the historical data under analysis. In particular the Romantic wholistic view of the world, its phenomenalism, its models for the education of university scholars, their interactions with French culture and especially Positivism, together with religious questions and the specific features of Alsace, allowed us to explain the features of Wurtz's école, which distinguished it from their Parisian contemporaries.

As a maître Wurtz emerges as someone whose beliefs and practices relied on individual free initiative, independence from the state, cooperation between those sharing common goals. His attitude may be related to his Alsatian background, to the cultural traditions and entrepreneurial practices current in Alsace, to his Lutheran ethos and to his education in the German-like Gymnasium of Strasbourg. Thus, individual initiative was underlying, for instance, the funding system adopted by Wurtz's école which primarily relied on the private fees paid by Wurtz's élèves. In this way the administration of his laboratory contrasted with that of his Parisian counterparts whose laboratories were run with funds obtained upon private or official negotiations with official channels. Individual initiative and independence were also underlying his policy regarding his élèves' publications. Unlike their colleagues of the other Parisian écoles, these were allowed to publish under their own names, while receiving training.

Wurtz 's practices contrasted, therefore, with those of his French colleagues which were usually normative and based on centralised forms of control. Instead, Wurtz's behaviour as a maître emerges as closer to the precepts of Fichte, Schelling and Schleiermacher, in which the figure of the master was supposed merely to provide guidance in a process of self-cultivation, allowing individual freedom and personal originality. In addition, Wurtz's internationalist ethos, which substantiated in his multinational personal, professional and institutional contacts, was itself close to the Romantic ideal of cosmopolitanism and international communication that, accordingly, should exist among scholars. This attitude impressed on his école a strong international dimension, which is one of its landmarks, materialising in the multiple national origins of his élèves.

Wurtz's élèves, although their various national origins had in common particular aspects which reinforces the idea of the existence of an European trend which was propagated to America, and was still impregnated by Romantic ideals. Thus, travelling, with or without scientific purposes; multiple contacts with different intellectuals and savants; the choice of usually more than one master in a process of seeking self-cultivation; knowledge of various languages; individual and collective publications not only on chemistry but also on popularisation, history of science, and translations; establishment of further research laboratories after the completion of a training period seen as a part of education; explicit manifestation of cultural interests in other areas than chemistry, including not only other sciences but also philosophy, history, music, literature and poetry, clearly indicates the presence of elements of the Romantic models of education of scholars.

Finally, in relation to the système underlying Wurtz's école was Gerhardt's type theory and associated atomic theory. The origins of this theory may be found in the model provided by Romantic comparative anatomy - the organic model. This model seems to have permeated much of the 19th century scientific thought despite the strong empiricist trend generated by Positivism. Unlike his more serious French adversaries, Wurtz's école was in the line of this organic model whose purposes were primarily classificatory, aiming at an unified chemical knowledge in which both mineral and organic chemistry were governed by the same rules. This model was to ascribe a third dimension in depth to organic substances, by linking internal groupings of atoms and their chemical functions. The relations within these atomic groupings were represented in chemical formulae defining a set of primitive types, which were abstract representations derived from the empirical study of reactional behaviour. The tensions inherent in the organic model, i.e., between what remains permanent (radical) in a succession of reactions and what changes (function), led to further adaptations of Gerhardt's theory, which had focussed mainly on functional aspects. In this process Wurtz's école played a major role in the transition from types to structures.

All these aspects suggest that a more extensive research on ideas, concepts, and models made available by the Romantic Movement and of their impact and influence on fields like science and scientific organisation in the course of the 19th century is still required.

Finally an evaluation of Wurtz's école may be carried out taking into account both the French and the international contexts. One of the striking aspects of Wurtz's école is undoubtedly the great number of élèves, which found no parallel in the other Parisian écoles. Especially the high proportion of foreigners, provides evidence for concluding of the international reputation of Wurtz's school, showing that it was not confined to French internal consumption. This recognition was itself associated with the integration of Wurtz's école in the international circuit of schools of chemistry as an almost final stage in a training process. This same recognition is, in addition, corroborated by many testimonies of Wurtz's French and foreign former élèves as well as by those of foreign well-established chemists like Kekulé, Hofmann, Williamson and Cannizzaro.

In France, the number of prizes awarded to Wurtz's élèves, notably the Jecker Prize (for organic chemistry) of the Académie des Sciences, indicates that despite the isolated position of Wurtz's école as regards chemical theory within the French context of schools of chemistry, the factual results obtained were sufficiently effective not to be denied. By factual results are meant, the new methods of preparation and the preparation of new compounds which, had been possible thanks to the capacity for prediction based on the theoretical framework.

Both in France and abroad Wurtz's école had become influential by founding and administering important scientific institutions, particularly the Société Chimique de France. In the French scene its influence was also exerted on educational institutions such as the Faculty of Medicine, the Ecole Alsacienne and the Ecole Municipale de Physique et de Chimie Industrielles, whose innovations were to inspire later reforms in the French teaching system.

Another indicator of the importance of Wurtz's école was not only the number of research papers as a whole but also the recognition of their quality, which is reflected at the time by numerous acknowledgements and many translations in foreign journals. In addition the textbooks, published by Wurtz and several of his élèves of the hard-nucleus circulated abroad and were also often translated

As a final conclusion we may say that owing to its sociological and scientific importance in the French and international scenes, Wurtz's école clearly deserves to be brought out of the obscure situation to which it has been relegated by historiographic criteria still very much relying on canons of 19th century official history.

APPENDIX 1

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

NAMES	COUNTRY OF ORIGIN	TIME SPENT WITH WURTZ	RESEARCH AREA	NUMBER OF RESEARCH PAPERS		
				ALONE	WITH WURTZ	WITH WURTZ'S ELEVES
CAVENTOU, Eugène (1823 1912)	FRANCE	1845-1884 (FML)[1]	.Anal. Chem. .Org. Chem. .App. Chem.	15 (1845-1874)	-----	2 Willm (1869-1870)
LUNA, Ramon M. (?-?)	SPAIN	1851?-1852? (FML)	.Anal. Chem. .App. Chem.	2 (1851-1852)	-----	-----
RISLER, Eugène (1828 1905)	FRANCE (Alsace)	1851 1852 (PL)[3]	.Anal. Chem. .App. Chem.	----	fn[2]	----
MARCET, William (1828-1900)	SWITZERLAND	1851-1852? (PL)	.Phys. Chem.	2 (1851-1852)	fn[4]	
SCHEURER-KESTNER, Aug. (18331889)	FRANCE (Alsace)	1852(PL)-1853 (FML)	.Org. Chem. .App. Chem.	fn[5]	-----	----
PERROT, Adolphe (1833 1887)	SWITZERLAND	1852-1853(PL) 1853 1863(FML)	.Org.Chem. .Physics	15 (1853-1863)	-----	----
de CLERMONT Philippe (1831 1921)	FRANCE	1852-1868[6] 1868-1876	.Org. Chem.	6 (1852-1868) 9 (1868-1876)	----	2, Silva (1869-1876)
MOSCHNIN (? ?)	?	1853?-1854?	.Org. Chem.	1 (1853)	----	----
HUMANN, Edmond (? ?)	FRANCE (Alsace?)	1853?- 1855?	.Org. Chem.	1 (1855)	----	----
FRIEDEL, Charles (1832 1899)	FRANCE (Alsace)	1854-1866[7] 1866-1884	.Org. Chem. .Min. Chem. . Spectrosc.	GN 8 (1854-1884)	1 (1861)	4, Machuca (1861-1862) 52, Crafts (1864-1889) 14, Ladenburg(1866-

[1] FML Faculty of Medicine's laboratory. From 1853 onwards all the research was carried out in the laboratory of the Faculty of Medicine.

[2] He published one article with Verdeil.

[3] PL- Private laboratory at Rue Garancière.

[4] He published one article with Verdeil.

[5] Scheurer Kestner only published research papers between 1857 until 1896, which suggests that the training received at Wurtz's laboratory may have been concerned with practical problems as he was the proprietor of chemical factories.

[6] Due to his post at the Ecole Pratique des Hautes Etudes at the Sorbonne, from 1868 he was entitled to use the corresponding laboratory where he carried out research and gathered some élèves. (See subsequent TABLES and DIAGRAM 1 in Chapter 3).

[7] In 1866, in association with his position he was given a small laboratory at the Ecole des Mines, where he gathered some élèves.(See TABLE IV and DIAGRAM 1 in Chapter 3)

[8] GN Great number of papers.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

						1880) 19, Silva (1869-1873)[9]
BUTLEROV, Alexandre (1828-1886)	RUSSIA	1857-1858 (2 months)	.Org. Chem.	1 (1858)	-----	-----
COUPER, Archibald, Scott (1831-1892)	G. BRITAIN (Scotland)	1857-1858	.Org.Chem.	2 (1857-1858)[10]	-----	-----
LIEBEN, Adolph (1836 1902)	AUSTRIA/ HUNGARY (Austria)	1857-1861	.Org. Chem.	7 (1857-1861)	-----	fn[11]
SIMPSON, Maxwell (1815 1902)	G. BRITAIN (Ireland)	1857-1859 1867	.Org. Chem.	4 (1857-1859) 1 (1867)	-----	1, Gautier (1867)
FRAPPOLI, Agostino (?-?)	ITALY	1857 1858	.Org. Chem.	----	1 (1858)	----
ATKINSON, Edmund (1831 1901)	G. BRITAIN (England)	1858-1859?	.Org. Chem.	fn[12]	-----	-----
FOSTER, George Carey (1835 1919)	G. BRITAIN (England)	1859?-1860	.Org. Chem.	1(1860)	-----	-----
BEILSTEIN, Konrad Friedrich (1838 1906)	RUSSIA [13]	1859-1860 1864?	.Org.Chem.	4? (1859)[14]	-----	fn[15]
LOURENÇO, A. Vicente	PORTUGAL (India)	1859-1861	. Org.Chem.	7 (1860-1861)[16]	-----	2, Reboul (1861)

[9] After Wurtz's death he published several articles with Combes.

[10] During his life Couper only published 3 articles. In one of these he presented his theory on chemical formulae which contradicted Wurtz's views. This question will be discussed in Chapter 5.

[11] After leaving Wurtz's laboratory he published with Bauer (1860).

[12] Atkinson was mentioned by Wurtz himself as one of his élèves. He published an article entitled "On monoacetate of glycol", Phil.Mag., 15 (1858), 433-438 in which he mentioned Wurtz since he was modifying his method of preparing glycol. He did not mention, however,that the research had been carried out at Wurtz's laboratory. This paper was also published in the Ann.Chim., [3] 56 (1859), 119-120. Wurtz acknowledged Atkinson's contribution in his "Histoire Générale des Glycols", (Paris, 1860) and "On oxide of ethylene considered as a link between organic and mineral chemistry", Chem. Soc. Journ., 15 (1862), 387-406.

[13] Beilstein was born in Russia, but his family was of German origin. This fact is relevant in the context of the Academy of St. Petersburg where there were two rival factions, the German and the Russian, and this may partially explain the problems involved in the election of Mendeleev (See Chapter 3). The interaction between German and Russian cultures was particularly important during this period. This exchange especially occurred in the Baltic states and particularly in intellectual centers such as Dorpat and Riga. For instance Claus and W. Ostwald were graduates from Dorpat and their careers are good examples of this mutual influence.

[14] Only in one of these papers was Wurtz's laboratory mentioned. At least, until 1860 Beilstein's work followed closely Wurtz's programme. In 1860, back in Göttingen, he showed that Wurtz's ethyledene was the éther hydrochlorique monochloridée of Regnault

[15] He published with Alexeev one joint article (1864) when the latter was in Göttingen before coming to Wurtz's laboratory.

[16] Lourenço followed by Maxwell Simpson were the élèves that Wurtz acknowledged most in the 1860s, notably in his "Histoire Générale des glycols" and in the lecture he delivered in England entitled "On oxide of ethylene

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

(1826 1893)						
NAQUET, Alfred (1834 1916)	FRANCE	1859-1862 1865 1869	.Org.Chem.	4(1859 (1869	------	2, Luguinin (1866)
REBOUL, Pierre E. (1829-1902)	FRANCE	1860-1861	.Org. Chem.	3 (1860-1862)	-----	2, Lourenço (1861)
SAWITSCH,[17] V. (?-1863?)	RUSSIA	1860?-1861?	.Org. Chem.	5 (1860-1861)	----	---
BAUER, Alexander (1836 1921)	AUSTRIA/ HUNGARY (Hungary)	1860-1861?	.Org.Chem.	3 (1860-1861)	-----	fn[18]
MACHUCA,P.V. (?-?)	SPAIN? (Cuba?)[19]	1860-1862?	.Org. Chem.	1 (1860)	-----	3, Friedel (1861-1861)
ALEXEEV, P. P. (1840 1891)	RUSSIA	1860-1861?[20] 1864	.Org.Chem.	1 (1861) 1(1864)[22]	----	fn[21]
OSER, Johann (1833 ?)	AUSTRIA/ HUNGARY	1861?-?	.Org.Chem.	1 (1861)	-----	-----
SCHIFF, Hugo (1834-1915)	GERMAN STATES	1861 1863?	.Org.Chem.	1.(1861)[23] 7?(1863)	-----	-----
OPPENHEIM, Alphonse (1833 1877)	GERMAN STATES	1861-1867 [24]	.Org.Chem.	7 (1863-1867)	-----	1, Pfaundler (1865) 1, Lauth (1867)
LAUTH, Charles (1836 1913)	FRANCE (Alsace)	1861[25]	.Org. Chem.	2 (1861)	-----	4, Grimaux (1866-1867) 1, Oppenheim

consisdered as a link between organic and mineral chemistry". On the other hand, Lourenço acknowledged the work of Wurtz, Atkinson and Simpson.

17 Sawitsch while attending Wurtz's laboratory was involved in a question of priority with an élève of Butlerov. Wurtz sorted out the question by guaranteeing their respective rights on the method of preparation of acetelyne they had devised. Both élèves were already dead in 1865. See letter sent on 14 February 1861 by Wurtz to Butlerov. BYKOV, G.V.; JACQUES, J., "Deux pionniers de la chimie moderne, Adolphe Wurtz et Alexandre M. Boutlerov, d'après une correspondance inédite", Rev.Hist.Sci., 13 (1960),115-134 (116).

18 After leaving Wurtz's laboratory he published a joint paper with Lieben in 1862 and with Lippmann in 1869.

19 In 1866 his address given in the Bulletin de la Société Chimique was in Havana.

20 In 1862 he was working at Tübingen with Wurtz's friend Strecker. He was mentioned in Beilstein obituary as his contemporary at Wurtz's laboratory. See GAUTIER, A. "Notice sur Frédérick C. Beilstein", Bull.Soc.Chim.Fr. 35 (1906), 1-4 (1).

21 .He acknowledged Wurtz in this article and mentioned that he is continuing the investigations he had begun at Göttingen. See "Sur la réduction de la nitrobenzine par l'amalgamate de sodium", Bull.Soc.Chim.Fr., 1 (1864), 324 326 (326). This suggests that between 1862 and 1864 he had attended German research laboratories.

22 In 1864 he also published an article with Beilstein.

23 Schiff does not mention Wurtz's laboratory in his memoirs, but he was listed by Friedel as one of Wurtz's élèves. This situation occurred with other chemists who already held posts in foreign universities. At the time Schiff was in Florence. The dates above correspond to periods during which his articles were published in French journals, suggesting perhaps several visits to his friend in Paris.

24 Friedel mentioned in his obituary of Wurtz that Oppenheim intended to spend six months in Wurtz's laboratory, but he spent six years.

25 He continued to carry out research at Wurtz's laboratory occasionally, after 1861.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

			.Min.Chem. .Appl.Chem.			(1867) 1, Vogt (1883)
LAUTEMANN, Eduard (?-?)	?	1862?-?	.Org. Chem.	1 (1862)	----	----
CRAFTS, James Mason............ (1839-1917)	USA	1862 1866[26] 1874-1891	.Org.Chem.	25 (1862-1883)	----	52, Friedel (1864-1889) 1, Silva[27] (1871)
WILLM, Edmond (1833- 1910)	FRANCE (Alsace)	1863-1884	.Anal. Chem.	GN (1863-1884)	1 (1871)	2, Caventou (1869-1870) 3, Girard (1875-1876)
SILVA, Roberto Duarte (1837 1889)	PORTUGAL[28] (Cabo Verde)	1863-1873 [29] 1873-1884	.Org. Chem.	GN (1863-1884)	----	1, Clermont (1869) 19, Friedel (1869-1873) 1, Crafts (1871)
GAUTIER, Armand (1837 1920)	FRANCE	1864-1874[30] 1874-1884	.Org. Chem. .Bio. Chem.	GN	----	1, Simpson (1867) 3, Cazeneuve / Daremberg (1874-1875)
BOLTON, Henry C. (1843 1903)	USA	c.1863 ?	----	31	----	----
MICHAELSON, Karl A. (1836 187?)	SWEDEN	1864-1866	.Org. Chem.	2 (1864)	----	2, Lippmann (1865)
MENSCHUTKIN Nikolai A. (1842 1907)	RUSSIA	1864-1865	.Org.Chem.	3, (1864-1865)	----	----
ZAYTZEV, Alexander M., (1841 1910)	RUSSIA	1864 1865	.Org.Chem.	1, (1865)	----	----
MAYER, Auguste (? ?)	?	1864 ?	.Org. Chem.	1, (1864)	----	----

26 In the case of Crafts his association with Friedel has to be taken into account. Between 1874 and 1891 he came to Europe for health reasons and he carried out research especially at Friedel's laboratory at the Ecole des Mines, but also occasionally at Wurtz's laboratory.

27 The research involved in this joint article was carried out in Williamson's laboratory in England due to the Franco Prussian war. See "Sur la préparation et les éthers de l'oxyde triethylphosphine", Bull.Soc.Chim.Fr., 16 (1871), 43 55 (55).

28 He later acquired French nationality.

29 Associated with his post at the Ecole des Arts et Manufactures he was allocated a small laboratory.

30.He was given a laboratory for biological chemistry in 1874 where he gathered some élèves. (See subsequent TABLES and DIAGRAM/, Chapter 3).

31.He only published research papers after 1866 in American journals.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

SALET, Georges (1844-1894)	FRANCE	1865-1884[32]	.Spectros. .Phys.Chem. .Org. Chem. .Inst.meths./ Techs.	GN	------	----
LIPPMANN, Eduard (1839 1920)	AUSTRIA/ HUNGARY (Checoslov.)	1865 1869?	.Org. Chem.	c.12[33] (1865-1869)	------	2,Michaelson (1865) 1,Luguinin (1867) 1,Sell (1866)
PFAUNDLER, Leopold (1839 1920)	GERMAN STATES	1865-1866?[34]	.Org. Chem.	1 (1865)	----	1,Oppenheim (1865)
SELL, Eugen ((1841 1896)	GERMAN STATES	1865- 1866?	.Org.Chem.	1 (1865)	-----	1, Lippmann (1866)
LUGUININ, Wladimir (1842 1896)	RUSSIA	1865-1867?[35]	.Org. Chem.	------	----	1, Naquet (1866) 1,Lippmann (1867)
LEVERKUS, ? (? ?)	?	1866?	.Org. Chem.	-----	----	1, Ladenburg (1866)
GRIMAUX, Edouard (1835 1900)	FRANCE	1866-1873[36] 1879-1881	.Org. Chem.	GN	-----	4, Lauth (1866-1867) 6, Adam (1879-1881) 1, Tcherniak (1879)
CLEVE, Per T. (1840-1905)	SWEDEN	1866?-1867? 1871	.Org. Chem. .Min. Chem.	2 (1867, 1871)?[37]	------	----
THIERCELIN, L. (? ?)	FRANCE	1866-1880?	.Anal. Chem. .App. Chem.	5 (1866-1880)	----	-----
LADENBURG, Albert (1842 1911)	GERMAN STATES	1866-1868	Org. Chem.	3 (1866-1868)	--- -	7, Friedel[38] (1866-1868) 1, Leverkus

[32] During his early years at Wurtz's laboratory he met among others Grimaux, Gautier, Caventou, Crafts, Perrot, de Clermont,Willm, Vogt, Girard, Beilstein, Oppenheim, Lippmann and Tollens. See FRIEDEL, "Notice sur la vie et les travaux de Georges Salet", Bull.Soc.Chim.Fr., 12 (1894), 7 23 (180).

[33] The exact number was impossible to determine because some of his papers (1869s) were published in foreign journals which were not available to me.

[34] He attended also Regnault's laboratory,while in Paris.

[35] He later became an élève of Berthelot (1869).

[36] Grimaux spent two distinct periods with Wurtz. (See subsequent Tables).

[37] Clève published papers in French in The Bulletin of the Société Chimique in 1863,1865,1867,1874,1875,1876,1877,1882. This suggests several visits to Wurtz's laboratory. As he did not acknowledge Wurtz's laboratory in his papers and was admitted as a member of the Société in 1866, I assumed that he entered the laboratory in 1866. He was listed by Friedel as one of the subscribers of the statuette given to Wurtz by his élèves and Poggendorf mentioned that he visited several foreign laboratories between 1866 1867, including that of Wurtz. As Clève was also mentioned by Partington as having carryed out part of his research on amines of platinous compounds at Wurtz's laboratory I only considered these two articles.

[38] He may have returned to Paris between 1872 1880 because he published about 8 articles, with Friedel in this period.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

						(1866)
ROUSSILLE, Albert (?-?)	FRANCE	1866-?	.Org.Chem.	2 (1866)	-----	----
WHEELER, Gilbert (? ?)	USA?	1867	.Org.Chem.	1(1867)	----	----
BUCHANAN, John Young (1844-1925)	G. BRITAIN (Scotland)	1867-1868	.Org.Chem.	2 (1867-1868)	-----	----
HENNINGER, Arthur (1850-1884)	GERMAN[39] STATES	1867-1884	.Org.Chem. .Bio. Chem .Instmeths./ Techs.	11 (1867-1884)	1 (1885)	1,Tollens (1869) 1,Darm-stäedter(1870) 2,Vogt(1872, 1882) 1, LeBel (1874)
FEBVRE, ?	FRANCE	1867 1875	?	?	---	?
PICTET, Raoul (1856 1929)	SWITZERLAND	1868-1870	Physics?	?	----	---
TOLLENS, Bernhard (1841 1918)	GERMAN STATES	1868-1869	.Org.Chem.	4 (1868-1869)	-----	1, Henninger (1869)
DARM-STÄEDTER, Ludwig (1842 1927)	GERMAN STATES	1869 1870	.Org. Chem.	-----	-----	1, Henninger (1870)
DOBROSLAVIN Alexis (? ?)	?	1870 1871?	.Bio. Chem.	2 (1870-1871)	----	-----
VOGT, Georges (? ?)	FRANCE (Alsace)	1870-1882?	.Org. Chem.	----	1 (1872)	2, Girard (1870-1871) 2,Henninger (1872-1882)
GIRARD, Adam Charles (1837 1918)	FRANCE	1871 1880	.Org. Chem. .App. Chem.	-----	-----	2, Vogt (1870-1871) 3,Willm (1875-1876) 1,Pabst(1880)
DAREMBERG, Georges (? ?)	FRANCE (Alsace?)	1872-1874	.Bio.. Chem.	1 (1872)	-----	1,Gautier / Cazeneuve (1874) 1 Cazeneuve (1874)
FRANCHI-MONT Antoine P. (1844 1919)	HOLLAND	1872-1873	.Org. Chem.	2(1872-1873)	-----	----

39 He acquired French nationality after the Franco -Prussian war.

40 He published s several articles with Combes in 1891.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

LE BEL, Joseph Achille (1847-1930)	FRANCE (Alsace)	1872 1884	.Org.Chem. .Inst meths./ Techs.	GN	----	1,Henninger (1874) 4,Greene (1878-1880) fn[40]
VAN'T HOFF, Jacobus (1850-1903)	HOLLAND	1874-	.Org.Chem.	?	----	----
DANLOS, H. (?-?)	?	1874-1880	.Biol.Chem.	?	----	----
BASAROV, Alexander (1845 ?)	GERMANY	1874-1875?	.Org. Chem.	2, (1874)	----	----
MAGNIER de la SOURCE, Louis (1850 ?)	FRANCE	1874-1876	Bio.Chem. .Inst meths./ Techs.	1 (1876)[41]	----	----
CAZENEUVE, Paul, (1852 1934)	FRANCE	1874-1879?	.Bio. Chem.	fn[42]	----	1Gautier/ Daremberg (1874) 1,Daremberg (1874)
DUPRE, Anatole (? ?)	FRANCE (Alsace)	874? -1878	Anal. Chem. .Inst meths./ Tech.	7 (1876-1878)[43]	----	----
ŒSCHNER de CONINK, F. W. (1851-1917)	FRANCE	1874?-1884	.Org. Chem.	15 (1874-1884)	----	1,Pabst(1874)
PABST, Albert (? ?)	?	1874	.Org. Chem	----	----	1, Oeschner de Coninck (1874)
KLEIN, Daniel (1848 1887)	FRANCE	1875? 1883	.Org. Chem.	4 (1880)	----	----
LECOQ de BOISBAUDRAN (1838 1912)	FRANCE	1875-1877	. Min. Chem .Spectrosc.	1 (1877) (1875-1877)	----	----
TCHERNIAK,	RUSSIA[44]	1875 1877[45]	.Org. Chem.	6? (1875	---	1, Nevolé

41 He worked basically at Gautier's laboratory.

42 Although he considered himself also an élève of Wurtz, he worked especially with Gautier. I cannot check if some of his individual publications carried out at Wurtz's laboratory because the journals involved are not available to me.

43. Some of Dupré's investigations were suggested by Boisbaudran as his work on gallium. See DUPRE, "Recherches sur la gallium", C.R., 86 (1878), 720-722 (720).

44 Later he was given French nationality by a special decree as a reward for having introduced into French industry a manufacturing process for the synthetic preparation of potassium and thiocyanates.

45 In 1877 he equipped a private laboratory and in 1878 he became administrator of the Compagnie Générale des Cyanures de Paris. However he still carried out research at Wurtz's laboratory as shown in the acknowledgements of his articles published in 1878-1879.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

Joseph (1851-1928)		1877-1883		1877)[46]		(1878) 5,Norton (1878-1883) 1, Grimaux (1879) 1, Hellon (1883)
POUPINEL, Gaston (?_?)	?	1875	?	?	----	----
GUNDELACH, Charles (?-?)	FRANCE (Alsace)	1876?-1880	.Org. Chem.	1 (1876)	-----	1,Michael (1880)
NEVOLE, Milan (? ?)	AUSTRIA/ HUNGARY (Checoslov.)	1876? 1878	Org. Chem.	3 (1876)	------	1, Tcherniak (1878)
GROSHEINTZ, Henri (1856 1931)	FRANCE (Alsace)	1876 1880	.Org.Chem.	4 (1876-1880)	----	----
RAYMAN, Bohuslav (1852 1910)	AUSTRIA/ HUNGARY (Checoslov.)	1876-1877	.Org. Chem.	2(1876-1877)	-----	----
HANRIOT, Maurice (1854 1935)	FRANCE	1876-1877[47] 1878-1884	.Org. Chem. .Bio.Chem.	GN	-----	fn48
GUNDELACH, Emile (? ?)	FRANCE (Alsace)	1876	.Org.Chem.	1 (1876)	----	----
GREENE, William H. (1853 1918)	USA	1877-1879	.Org. Chem.	13 (1877-1879)	-----	3, LeBel (1878-1879)
WASSERMANN Max (? ?)	?	1877? 1879?	.Org.Chem.	1 (1879)	----	----
NORTON, Thomas H. (1851 1941)	USA	1878-1883	.Org. Chem.	2 (1878-1883)	------	5,Tcherniak[49] (1878-1883)
VARENNE, Eugène (?-?)	FRANCE	1878?	.Min..Chem.	?	-----	-----
PATRY, Edouard	SWITZERLAND	1878 ?[50]	?	-----	-----	-----
RICHARD, J. Auguste (? ?)	FRANCE	1878 1879?	.Org.Chem.	1 (1879)	----	----

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[46] Some of these articles were published only in German journals, which are not available and consequently acknowledgements cannot be checked.

[47] He was préparateur of chemistry in the laboratory at the Faculty of Medicine between 1876-1877, but during this period he did not publish any research papers.

[48] He published joint papers with Richet in 1887-1888.

[49] Before attending Wurtz's laboratory (1876-1877), Norton published in Germany two articles with Michael, who in 1879 was to attend also the laboratory.of the Faculty of Medicine.

[50] Possible date of admission in Wurtz's laboratory, since he also entered the Société Chimique in 1878.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

BOUCHUT, H. (? 1891)	FRANCE	1879?-?	.Org. Chem.	1 (1880)	1 (1879)	----- fn 51
MICHAEL, Arthur (1853 1916)	USA	1879-1880?	.Org. Chem.	1 (1879)	-----	1,Gundelach,C (1880)
TATARINOV, Paul (?-?)	?	1879?	.Org.Chem.	1 (1879)	-----	-----
FAUCONNIER, Adrien (1858-?)	FRANCE	1879-1884	Org. Chem. .Biol.Chem.	1 (1882) 52	-----	-----
GUEBHARD Adrien (1849 1903?)	FRANCE	1879-1888	--- (Physics)53	-----	-----	-----
ADAM, Paul (1856 1916)	FRANCE	1879-1881	.Org.Chem.	-----	----	7, Grimaux (1879-1881)
GRAWITZ, Samuel (? ?)	FRANCE	1880-?	.Org.chem.	?	-----	-----
MORLEY, Henry F. (1855 1916)	G. BRITAIN (England)	1880 ?	.Org.Chem.	1 (1880)	-----	-----
POUCHET, A. Gabriel (1851-1931)	FRANCE	1880 1883	.Bio. Chem.	fn54	-----	-----
BROGNIART, Charles55 (? ?)	FRANCE	1880 1881	Org. Chem.	-----	-----	-----
DIETZ, Henri (? ?)	FRANCE (Alsace?)	1880-1881	.Org.Chem.	-----	-----	-----
DUBOIS, Charles (? ?)	FRANCE	1880-1881	.Org. Chem.	-----	-----	-----
PICTET, Amé 56 (1857 1937)	SWITZERLAND	1881?-1882	.Org.Chem.	1 (1882)	-----	-----
WALITZKY, W. E. (? ?)	?	1881 1882	.Org. Chem.	2 (1881-1882)	-----	-----
PLIMPTON, Richard Tayler (1856-?)	GREAT BRITAIN (England)	1881? -?	.Org.Chem.	2 (1881)	-----	-----

51 He cooperated with Wurtz and Henninger when they studied the application of papaine to tumors in patients of St. Louis Hospital.

52 He published a paper in 1880 in which he acknowledged Gautier's laboratory.

53 He held a junior teaching post at the physics laboratory of the Faculty of Medicine.

54 He published in medical journals not available to me.

55 Brogniart was related to Dumas's wife who also belonged to this family of renowned savants.

56 Both Amé and Raoul Pictet were related to a family of savants of Geneva. Their ancestor Marc Auguste Pictet, an associate member of the Société d'Arcueil, had been professor of physics of Dumas while he lived in Geneva during his youth.

TABLE I - BASIC IDENTIFICATION OF WURTZ'S ELEVES IN CHRONOLOGICAL ORDER

NEWBURY, (? ?)	?	1881? ?	.Org.Chem.	1 (1881)	----	----
ŒCONOMIDES, Spiridon (? ?)	?	1881? ?	.Org. Chem.	1 (1881)	----	1, Hanriot (1881)
GRINER, G.(?-?)	FRANCE (Alsace)	1882	.Org.Chem.	?	----	?
COMBES, Alphonse (1858-1896)	FRANCE	1882-1884	.Org Chem.	2 (1882-1884)	-----	fn[57]
FERNBACH,[58] Auguste (1860-1939)	FRANCE	-----	----[59]	-----	----	----
ETARD,[60] Alexandre (1852 1910)	FRANCE	1880-1884	Bio.Chem.	-----	------	-----fn[61]
DEMARÇAY,[62] Eugène (1852-1904)	FRANCE	-----	-----	-----	-----	-----
RICHET, Charles (1850-1935)	FRANCE	?	?fn[63]	------	------	-----fn[64]
HELLON, R. (? ?)	?	1883?	. Org.Chem.	-----	------	1, Tcherniak (1883)

Note: I was unable to identify the following élèves: Bardet; Bayne; Broca; Chatin; Chenal; Clandon; Coffin Engelbach; Glaizot; Jayne; Kienlen; A. Kopp (Alsatian?); A. Kreiss (Alsatian, probably Wurtz's relative from hi: mother side); Leser (Alsatian); Michaielianu; Pierron; Roos, H.; A. Scheurer (Alsatian); G. Steinheil (Alsatiar ,probably Wurtz's relative); Trommsdorff, H.; Weyer; Werner, E.Burney; Emmonds; Herrera; Santos; Tibiriça Weisgerber.

57 See notes 9 and 48.

58 He was an élève of Pasteur, but he also considered himself an élève of Wurtz. He participated in the editorial activity of Wurtz's école. (See subsequent TABLES).

59 His work was especially devoted to fermentation and its applications to the brewing industry.

60 He was a devoted élève of Cahours, but he considered himself also an élève of Wurtz. He enrolled in the editorial acctivity of Wurtz's école.(See susequent TABLES)

61 He published with Gautier and Richet.

62 He was a devoted élève of Cahours, but he considered himself also an élève of Wurtz. He enrolled in the editorial acctivity of Wurtz's école.(See susequent TABLES). Demarçay devoted mainly to investigations on rare earths and spectroscopy. He notably discovered the element Europium.

63 Richet , despite being a physiologist was interested in many other fields including biological chemistry, aviation, espiritualism and psychic pheneomena. He had contacts with the British writer Sir Arthur Conan Doyle who often in cooperation with the physicist Sir Oliver Lodge carried out experiments on spiritualism.

64 See note 61.

TABLE II- INVOLVEMENT OF THE ELEVES IN SCIENTIFIC INSTITUTIONS

NAMES	SOCIETE CHIMIQUE de FRANCE (Founded 1857/1858)	ASSOCIATION FRANÇAISE POUR L'AVANCEMENT DES SCIENCES (Founded 1872)	
	Status	Status	Status in 6th section (Chem.)
CAVENTOU	Founder; Member; Treasurer (1863-1872)	Founder; Member	-----
LUNA	Member (1858)	----	----
RISLER	Member	Founder; Member	----
MARCET	?	----	----
SCHEURER-KESTNER	Member (1858); President (1894)[1]	Founder; Member	----
PERROT	Founder; Member; Archivist (1858)[2]	----	----
de CLERMONT	Founder; Member of the Council (1858-1921) Secretary (1875-1882); President (1886)	Founder; Member	Member of the Board (1880-1883)
MOSCHNIN	?	----	----
HUMANN	Member	----	----
FRIEDEL	Founder; Member of the Council (1858-1899) Secretary (1862) ; President (1870, 1880, 1888)	Founder; Member; Archivist (1872-1876)	Member of the Board (1877-1879); (1882-1883); President(1881)
BUTLEROV	Founder; Member[3]	----	----
COUPER	Founder; Member[4]	----	----
LIEBEN	Founder; Member; Honorary Member[5]	----	----

[1] In 1894 together with Friedel he launched a campaign among industrialists to raise funds for the Société Chimique, which was near bankrupcy.

[2] He later became President of the Société Genevoise pour la Construction d'Instruments de Physique.

[3] Butlerov and the élèves mentioned below were among those young chemists who had the idea of creating the Société. They used to meet informally in a café in the Quartier Latin to discuss the foundation of that institution. See GAUTIER, "Le cinquantenaire de la Société Chimique de France", Rev. Sci., 7 (1907), 641-689 (643).

[4] With others he was admitted on 5 January 1858, through Lieben:

> Présentation par M. Lieben de MM. Cooper et Sympson (sic) comme candidats au titre de membres de la Société. Ces messieurs sont reçus à l'unanimité.

Quoted from JACQUES, "Boutlerov, Couper et la Société Chimique de Paris", Bull.Soc. Chim. Fr., 20 (1935), 528-530 (528). Butlerov was also member of the Russian Chemical society from 1869 and between 1872 and 1882 he became chairman of the chemistry section of the Russian Physics and Chemistry Society (founded in 1878 through the fusion of the Chemical Society with that of Physics).

5 See note 3.

TABLE II- INVOLVEMENT OF THE ELEVES IN SCIENTIFIC INSTITUTIONS

SIMPSON	Founder; Member[6]	----	----
FRAPPOLI	Founder; Member[7]	----	----
ATKINSON	[8]	----	----
FOSTER	Member[9]	----	----
BEILSTEIN	Member	----	----
LOURENÇO	Member	----[10]	----
NAQUET	Member	----	----
REBOUL	Member; Member of the Council	Member	----
SAWITSCH	Member	----	----
BAUER	Member	----	----
MACHUCA	Member	----	----
ALEXEEV	Member	----[11]	----
SCHIFF	?	----	----
OPPENHEIM	Member	----[12]	----
LAUTH	Member; Member of the Council (1867); Vice President (1872); President (1883)	Founder; Member	----
LAUTEMANN	Member	----	----
CRAFTS	Member	----	----
WILLM	Founder; Member; Archivist (1866-1867) Secretary (1867); President (1884)	Founder; Member	----

6 See note 3.He was also member of the British Association for the Advancement of Science (BAAS) and became President of the chemical section in 1878..

7 See note 3.

8 He was member of the of the.BAAS and of the Physical Society of London.

9 He was an active member of the BAAS and of the Physical Society of London.

10 Lourenço was not a member, but participated as a foreign guest in the meeting of the Association Française pour l'Avancement des Sciences in 1878.

11 Alexeev was not a member, but participated in the meeting of the Association Française in 1879 as a foreign guest.

12 In the list of members of the Association Française there are the brothers Oppenheim (bank owners) whose address was in Paris. However, a possible relation to this Oppenheim cannot be verified.

TABLE II- INVOLVEMENT OF THE ELEVES IN SCIENTIFIC INSTITUTIONS

SILVA	Member; Vice President (1885); President (1887)[13]	Member; Secretary (1875-1877)	Member (1875-1877) President (1886)
GAUTIER	Member; Member of the Council (1872) President (1876, 1891, 1906)	Member	----
BOLTON	Member	----	----
MICHAELSON		----	----
MENSCHUTKIN	Member[14]	----	----
ZAYTZEV	Member	----	----
MAYER	?	----	----
SALET	Member; Vice Secretary (1872); Vice-President (1877)[15]	Member	----
LIPPMANN	Member	----	----
PFAUNDLER	Member	----	----
SELL	?	----	----
LUGUININ	Member	----	----
LEVERKUS	Member	----	----
GRIMAUX	Member; President (1881,1890,1900)	Member; Member of the Board (1882-1883)	Member (1873, 1874, 1880, 1884); President (1882)
CLEVE	Member	----	----
THIERCELIN	Member; Member of the Council (1867)	----	----
LADENBURG	Member	----	----
ROUSSILLE	Member	Member	----
WHEELER	Member	----	----

13 While he was President of the Société he took the initiative in promoting special meetings devoted to industrial chemistry. Silva left his personal library and belongings to the Société Chimique.

14 Menschutkin was one of the founders of the Russian Chemical Society and worked as its secretary until 1891. For thirty years he was also the editor of its journal.

15 He was also member fo the Council of the Société de Physique.

TABLE II- INVOLVEMENT OF THE ELEVES IN SCIENTIFIC INSTITUTIONS

BUCHANAN	Member[16]	----	----
HENNINGER	Member	Member	President (1882)
FEBVRE	Member	----	----
PICTET, R.	[17]	----	----
TOLLENS	Member	----	----
DARM-STÄEDTER	Member	----	----
DOBROSLA-VIN	Member	----	----
VOGT	Member ; Member of the Council	Member	----
GIRARD	Member ; Member of the Council (1876)	Founder, Member	----
DAREMBERG	Member	----	----
FRANCHI-MONT	Member	----[18]	----
LE BEL	Member; President (1892)	Member	----
VANT HOFF	----	----	----
DANLOS	----	----	----
BASAROV	----	----	----
MAGNIER de la SOURCE	Member	----	----
CAZENEUVE	Member	----	----
DUPRE	Member	Member	----
ŒSCHNER de CONINCK	Member, Secretary (1882-1883); President of Montpellier's section.	Member	----
PABST	Member	Member	----

[16] He was member of the London Geological Society.

[17] He was member of the Société de Phisique de Genève.

[18] Franchimont was not a member of the Association Française, but between 1875-1878 and 1882 1883 he participated in the annual meetings as a foreign guest.

KLEIN	Member	——	——
LECOQ de BOISBAUDRAN	Member	Founder, Member	Secretary (1872)
TCHERNIAK	Member	Member	——
POUPINEL	Member	Member	——
GUNDELACH,C	Member	——	——
NEVOLE	Member	——	——
GROSHEINTZ	Member[19]	——	——
RAYMAN	Member	——	——
HANRIOT	Member, General Secretary (1886-1893) President (1899)	——	——
GREENE	Member	——	——
WASSERMANN	Member	——	——
GUNDELACH, E	Member	——	——
NORTON	Member[20]	——[21]	——
VARENNE	Member	——	——
PATRY	Member	——	——
RICHARD	Member	Member	——
BOUCHUT	——	——	——
MICHAEL	Member	——	——
TATARINOV	Member	——	——
FAUCONNIER	Member	——	——
GUEBHARD	——	Member	——

[19] He was also a particularly active member of the Société Industrielle de Mullhouse like Lauth , Scheurer Kestner and other Alsatian elements of Wurtz's école.
[20] He was awarded the Lavoisier Medal of the Société Chimique in 1937.
[21] He was member of the American Association for the Advancement of Science and created the Cincinnati Chemical Society which later integrated the American Chemical Society..

ADAM	Member	Member	——
GRAWITZ	Member	——	——
MORLEY	Member [22]	——	——
POUCHET	Member	Member	——
BROGNIART	——	——	——
DIETZ	Member	Member	——
DUBOIS	——	——	——
PICTET, A.	Member	——	——
WALITZKY	Member	——	——
PLIMPTON	——	——	——
NEWBURY	Member	——	——
ŒCONOMIDES	Member	——	——
GRINER	Member	——	——
COMBES	Member; Vice-President (1891); President (1893)[23]	Member	Member (1891)
FERNBACH	Member	Member	——
ETARD	Member	Member	——
DEMARÇAY	Member	——	——
RICHET	Member	——	——
HELLON	Member	——	——
WEISGERBER	Member	——	——

22 He was a member of both the Chemical Society and the chemistry section of the BAAS.
23 He was also a member and belonged to the Board of directors of the Société de Physique.

TABLE III- INVOLVEMENT OF THE ELEVES IN EDITORIAL ACTIVITIES

NAMES	BULLETIN de la SOCIETE CHIMIQUE de FRANCE	DICTIONNAIRE de CHIMIE PURE et APPLIQUEE
	Editorial Status	Editorial Status
CAVENTOU	------	Member of the Editorial Board (1869 1878)
LUNA	Corresponding member of the Editorial Board (1863)	------
SCHEURER-KESTNER	Member of the Editorial Board (1864-1865)	------[1]
de CLERMONT	Translator (1858); Member of the Editorial Board (from 1865)	Member of the Editorial Board (1869- 1878)
FRIEDEL	Translator (1858); Member of the Editorial Board (from 1858)[2]	Member of the Editorial Board (1869-1878) (1880-1886); Chief editor (1892-1901)
LIEBEN	Collaborator of the Editorial Board (1863-1865)	-----
FRAPPOLI	Corresponding member of the Editorial Board (1863)	-------
FOSTER	Member of the Editorial Board (1858 1864)	-------
LOURENÇO	Collaborator of the Editorial Board (1863)	------
NAQUET	---- -	Member of the Editorial Board (1869-1878)
SAWITSCH	Corresponding member of the Editorial Board (1863)	-------
LAUTH	Collaborator of the Editorial Board (1867	Member of the Editorial Board (1869-1878)
WILLM	Member of the Editorial Board (from 1864) Secretary of the Editorial Board (1875)	Member of the Editorial Board (1869-1878); (1880-1886); (1892-1901)
GAUTIER	-------	Member of the Editorial Board (1869-1878); (1880-1886)
SALET	Member of the Editorial Board (from 1870)	Member of the Editorial Board (1869-1878); (1880-1886); (1892-1901)

1 Although not a member of the editorial board he contributed several articles to the dictionary .

2 Especially after Wurtz's death his role as editor became decisive. See HANRIOT, "Notice sur la vie et les travaux de Charles Friedel" ', Bull.Soc.Chim Fr., 24 (1900), 1 56 (8)

TABLE III- INVOLVEMENT OF THE ELEVES IN EDITORIAL ACTIVITIES

GRIMAUX	Member of the Editorial Board (from 1882)	Member of the Editorial Board (1869-1878); (1880-1886); (1892-1901)
CLEVE	Member of the Editorial Board (from 1873) Responsible for the section "Correspondance Suédoise" (1874-1877)	Member of the Editorial Board (1880-1886); (1892 1901)
THIERCELIN	------	Member of the Editorial Board (1869-1878)
HENNINGER	Member of the Editorial Board (from 1870)	Member of the Editorial Board (1869-1878); (1880-1886); (1892-1901)
TOLLENS	Member of the Editorial Board (1869)	------
VOGT	Member of the Editorial Board (1870-1874)	Member of the Editorial Board (1869-1878); (1891-1901)
GIRARD	Member of the Editorial Board (1871-1883)	Member of the Editorial Board (1869-1878); (1880-1886)
DAREMBERG	Member of the Editorial Board (1873-1874)	------
LE BEL	------	Member of the Editorial Board (1880-1886)
OESCHNER de CONINCK	Member of the Editorial Board (from 1878) Secretary of the Editorial Board (1882-1883)	Member of the Editorial Board (1880-1886)
PABST	Member of the Editorial Board (1875 1883)	------
TCHERNIAK	------	Member of the Editorial Board (1880-1886)
GUNDELACH C.	Member of the Editorial Board (1880)	------
GROSHEINTZ	Member of the Editorial Board (1878-1880)	------
HANRIOT	Chief Editor (after 1884) Editor of the lectures delivered at the Société Chimique in three separate volumes (1882-1893)	Member of the Editorial Board (1880-1886); (1892-1901)
WASSERMAN	Member of the Editorial Board (1880)	Member of the Editorial Board (1880-1886)
FAUCONNIER	Member of the Editorial Board (from 1882)	Member of the Editorial Board (1880 1886) (1892-1901)
ADAM	Member of the Editorial Board (from1883)	Member of the Editorial Board (1892-1901)
COMBES	Member of the Editorial Board (from1884)	Member of the Editorial Board (1892-1901)

TABLE III- INVOLVEMENT OF THE ELEVES IN EDITORIAL ACTIVITIES

FERNBACH	Member of the Editorial Board (1879-1883)	------
ETARD	Member of the Editorial Board (1880-1882)	Member of the Editorial Board (1880-1886); (1892-1901)
DEMARÇAY	-------	Member of the Editorial Board (1880-1886)

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

NAMES	POSTS	DOCTORATES	PRIZES	ACADEMIE des SCIENCES
CAVENTOU	.Wurtz's assistant FML[1] (1845 1884)	-----	---	----[2]
SCHEURER-KESTNER	.Industrialist .Private researcher .Senator	----	.Major Prize, Univ. Exhibition (1878) .Gold Medal, Société Industrielle de Mulhouse (1878) .Gold Medal, Société Industrielle de Lille (1888)	-----[3]
PERROT	.Préparateur FML (1853-1860)[5] (1860 1867)[6]	(1861)[4]	----	-----
de CLERMONT	.Attached to and later Assistant-director of the laboratory, EPHE, Sorbonne (1870s)[8] .Curator of Chemical Collections, Ec.Poly. (c.1875)[9]	(1870)[7]	.Jecker Prize (1870)	-----
FRIEDEL	.Préparateur of Dufrénoy[10]	(1869)[11]	.Jecker Prize (1865),	Member, Chem. Sec. [12]

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[1] He assisted Wurtz non-officially and was not paid. This post was a result of his father's(J.-B.Caventou), admiration for Wurtz and friendship with Dumas.

[2] He was member of the Académie de Médecine, and became its President in1897.

[3] He refused to conform with the election system.

[4] His thesis was entitled Recherches sur l'action chimique de l'étincelle de l'appareil de Ruhmkorff. Sur la nature de l'étincelle d'induction de l'appareil de Ruhmkorff, (Paris, 1861)

[5] Non officially.

[6] Officially.

[7] The thesis was entitled Recherches sur les composés octyliques, (Parie, 1870)

[8] The laboratory of the Ecole Pratique des Hautes Etudes at the Sorbonne was founded in 1868. The academic director was Wurtz's Alsatian friend Schutzenberger, but the director of the laboratory was Berthelot's disciple Riban. Here de Clermont had as colleagues Troost (Deville's élève), Gautier and Grimaux. The latter never adjusted to Riban's directorship.

[9] He succeeded Berthelot's devoted élève Jungfleisch and gathered a group of young researchers.

[10] Dufrénoy was Professor of Mineralogy and Director of the Ecole des Mines.

11.He presented two theses, one on organic chemistry and the other on mineralogy, whose titles were respectively Recherches sur les acétones et les aldéhydes and Sur la pyro électricité dans les cristaux bons conducteurs d'électricité, (Paris,1869).

[12] Pasteur, who had met Friedel as auditor of his courses in the University of Strasbourg, wanted him to be elected in his section, mineralogy. Friedel, however,preferred to wait and enter the chemistry section where he eventually succeeded Regnault. Like Wurtz, he was a member of the most renowned international scientific

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

	Ecole des Mines (1854) .Maître de conférences (1871), Professor of Mineralogy (1872), Ecol Normale .Prof. of Mineralogy, Sorbonne (1876) .Successor of Wurtz, Sorbonne (1884)		1869) .La Caze (1863)[13] . Faraday Medal (1880), Royal Inst	(1878)
NAQUET	.Agrégé, Univ. Mont-pellier (1860 1863) .Agrégé ,Fac.Med. Paris (1863) .Professor of Chemistry pellier (1860-1863) .Agrégé ,Fac.Med. Paris (1863) .Professor of Chemistry in Palermo (1863-1865)[15] .Agrégé, Paris Fac. Medicine (1865-1869) . Political Exile in Spain (1869) .Commissioner of defenc (1870) .Politician (Socialist)[16] Deputy. (1871)	(1859)[14]	------	-----
REBOUL	.Wurtz's private assistan (1864s)[18] .Prof. of Chemistry, Sci. Fac.Besançon (1876) .Prof. of Chemistry, Dean Sci.Fac. Marseille (?)	(1860)[17]	. Jecker Prize (1874, 1878)	Corresp. Member, Chem. Section (1886)

academies and societies and was Doctor Honoris Causa of Oxford University.

13 The La Caze Prize was awarded every two years by the Académie des Sciences

14 The title of his thesis is not available.

15 This post may have been obtained through Wurtz's friendship with Cannizzaro who at the time was Professor in Palermo. See GAUTIER, A., "Stanislas Cannizzaro", Bull.Soc.Chim.Fr., 7 (1910), 1-10..

16 He became devoted exclusively to politics.

17 Reboul's dissertation was entitled Des éthers du glycide et de leurs relations avec les éthers glycériques, (Paris, 1860)

18 In his letter to Dumas (1 Feb.1864), Wurtz mentioned that Reboul was in charge of supervising élèves in his laboratory. Paris, Arch. Acad. Sci., Dossier Wurtz.

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

OPPENHEIM	------	____[19]	------	------
LAUTH	.Gerhardt's préparateur, Strasbourg Univ.(1854-1855) .Persoz's préparateur-adjoint, Cons.Arts et Métiers (1856) .Director of Sèvres Manufactures ((1879-1886) .Director of the Ecole de Physique et deChimie Industielles (1898-1905) .Vice President of Paris Local Council (1878s) .Industrialist	------	.1st Class Medal, Soc.Ind.Mulhouse (1865) .Gold Medal, Universal Exhibition (1867) .Platinum Medal, Soc. d'Encouragemnt de l'Industrie Nationale (1867) .Diploma of Honour, Universal Exhibition, Vienna (1873)	______[20]
WILLM	.Chef de travaux chimiques Paris Fac. Medicine (1867-1874) .Prof. of Chem, Univ. Lille (c.1890))	(1865)[21]	.Hydrology Prize, Académie de Médecine (1883)	------
SILVA	.Chef de travaux chimiques Ecole des Arts et Manufactures (1873) .Professor of Chemistry Ecole de Physique et de Chimie Industrielles (1878) .Professor of Anal. Chem., Ecole des Arts et Manufactures (1886)[24]	------	Jecker Prize (1885)[23]	_____[22]

19 He obtained his doctorate in Germany . (See subsequent TABLES).

20 He failed to be elected in 1890.

21 His thesis was entitled Recherches sur le thallium, (Paris, 1865)

22 He was a member of the Academia Real das Ciências de Lisboa (Portugal) (1876).

23 Silva together with Crafts were the only foreigners to whom the Jecker Prize was awarded between 1859 and 1894.

24 He succeeded Félix Le Blanc.

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

GAUTIER	.Assist director of the laboratory, EPHE, Sorbonne (1869) .Assist-director of the laboratory of Bio. Chem., Fac. Med. Paris (1874) .Director of the above laboratory (1875) .Chef de travaux pratiques, Fac.Med. Paris (1880) .Professor of Med. Chem. (1884)	(1875)[25]	Jecker Prize (1868)	Member[26] Chem.Sec. (1889)
SALET	.Préparateur, FML (1867)[29] .Chef de travaux pratiques, Fac.Med. Paris (1867 1775) .Wurtz's préparateur, Sorbonne (1875) .Maître de conférences of Org. Chem., Sorbonne(1878) .Professor of Org.Chem. Sorbonne (after 1884)	(1872)[27]	Silver Medal, Universal Exhibition, Paris (1878)	------[28]
GRIMAUX	.Lecturer on chemistry Fac.Med.Paris (1869, 1871,1873) .Assist-director of the laboratory, EPHE, Sorbonne (1873-1879)[31]	(1877)[30]	.Jecker Prize (1870, 1875)	Member,Chem.Section (1894)

25 His thesis was entitled Des nitriles des acides gras, (Paris,1869)

26 He was also a member of the Académie de Médecine and of several foreign academies and scientific societies.

27 His thesis was entitled Sur les spectres de métalloides, (Paris,1872)

28 In 1877 and 1878 he failed to be elected. The chemistry section of the Académie des Sciences considered his work not sufficiently related to chemistry. He was a member of the Société Philomatique.

29 He replaced Willm, who went temporarily to the University of Lille as chargé du cours.

30 His thesis was entitled Recherches synthétiques sur la série urique, (Paris,1877), but in 1886 he had passed the agrégation with a thesis completely devoted to chemical theory, whose title was Equivalents, atomes, molécules, (Paris, 1886).

31 The director was Wurtz's Alsatian friend Schutzenberger, but he left in 1876 and was replaced by Riban (Berthelot's élève). As Grimaux had deep disagreements with him he left and returned to Wurtz's laboratory.

→	.Répétiteur, Ecole Polytechnique (1876) .Prof. of chemistry, Institut National Agronomique (1876) .Prof. of Chem., Ecole Polytechnique (1881)[32]			
THIERCELIN	.Medical doctor retired from the Navy.	-----	-----	-----
HENNINGER	.Wurtz's private préparateur, FML(1867-1870) Exile in Switzerland (1870-1871) .Préparateur , FML (1875-1878) .Responsible for the complementary course on Org.Chem.,Fac. Med. Paris (1878) .Wurtz's suppléant,Fac. Med.Paris (1881) .Prof. of Chem., Ecole de Physique et de Chimie Industrielles (1882)	(1878)[33]	-----	-----
FEBVRE	.Préparateur, FML (1867 1875)	-----	-----	-----
BOUCHUT	.Medical Doctor	-----	-----	
RICHARD	Chemist in Mulhouse (before 1872) .Director of a porcelain factory in Milan, (from 1872)	-----	?	-----
VOGT	.Chemist, Sèvres Manufactures (after c.1870)	-----	-----	-----

[32] He succeeded Cahours. Later he was dismissed and deprived of his laboratory at the Ecole Polytechnique by the Ministry of war due to his involvement in Dreyfus case. Like Scheurer Kestner, he was a supporter of Dreyfus.

[33] His thesis was entitled Recherches sur les peptones, (Paris,1878).

GIRARD	.Manufacturer . Director of the Laboratoire Municipal (Contributions Immédiates) (from 1875)	----	-----	-----
DAREMBERG	.Medical Doctor	-----	----	-----
LE BEL	.Préparateur,FML (1869-1876) .Proprietor of Petroleum works, Alsace[36]	----	.Jecker Prize (1881) .Davy Medal, Royal Society (1893)[35]	Member, Chem.Section[34] (1929)
DANLOS	Préparateur, Biol. Chem. lab, Fac. Med., Paris, (1874-1880)	----	-----	-----
MAGNIER de la SOURCE	Medical Doctor (from 1875) Expert-chemist of the Tribunals, Paris (?)	-----	-----	------
CAZENEUVE	Agrégé,Chem., Fac. Med. Lyon (1880?) .Prof.of Chem. and Toxic.,Fac.Med. Lyon (from 1881)[39] .Deputy (1901-1920) .Senator (1920-1934)	37	.Jecker Prize (1890) .Gold Medal of Public Hygiene(?)	------[38]
DUPRE	Essayeur, Laboratoire Municipal (Contributions Immédiates) (from 1975)[40] .Préparateur, FML (1878	----	-----	------

34 He was in conflict with the Académie des Sciences for many years, but was finally elected in 1929. Like Wurtz he was first elected to the Royal Society (1911).

35 He was awarded at the same time as Van't Hoff.

36 In 1889 he sold his oil interests to engage entirely in chemical research. In his later years he devoted himself to paleontological and philosophical studies as well as to botany in his private botanical garden.

37 The title of his thesis is not available.

38 He was member of the Académie de Médecine.

39 This chair was especially created for him and he introduced for the first time the atomic theory in the teaching of that Faculty.

40 Previously, he held a post at the University of Strasbourg, but he came to Paris due to the Franco- Prussian war.

	1880)			
ŒSCHNER de CONINCK	.Wurtz's private préparateur, Sorbonne (1874-1884) .Prof. of Chem., Fac. Sci.,Montpellier (1892)	(1882)[41]	Jecker Prize (1886)	--------
PABST	?	---	----	-----
KLEIN	. Chemist, Raffinerie Parisienne (?)	(1883)[42]	-----	-----
LECOQ de BOISBAUDRAN	.Spirits trader .Private researcher	------	.Bordin Prize(Acad Sci.) (1872) .Davy Medal, Royal Society (1879) .LaCaze Prize (1879)	Corresp. Member, Chem.Sec.(1878)[43]
TCHERNIAK	.Administrator, Compagnie Générales des Cyanures, Paris. (1878 1883) .Private researcher/ on viticulture, Toulon (1883 1888)[45]	---[44]	-----	-----
GROSHEINTZ	.Chemist, Maison Scheurer Rott Cie (Thann,Alsace) (1876) .Préparateur,FML (1876-1880) .Chemist, Usines Scheurer Lauth Cie (Thann,	-----	-----	-----

41 His thesis was entitled Recherches sur les bases de la série pyridique et la série quinoléique, (Paris,1882).
42 The title was Sur les acides borotungstiques, (Paris, 1883)

43 Dumas suggested him as a possible candidate for election to the Académie des Sciences as permanent member, but he did not show any interest.
44 He passed his doctorate in Germany. (See subsequent TABLES)
45 His research on viticulture (phylloxera) was carried out in the vineyards he acquired in Toulon, since the Compagnie Générale des Cyanures had to close down due to lack of capital (1883). He was rewarded by the French Government for these studies.

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

	Alsace) (1880-1931)			
HANRIOT	.Préparateur, FML (1876 . 1877) .Medical doctor in the provinces (1877-1878) .Agrégé, Fac.Med.Paris (1880) .Wurtz's suppléant, Fac. Med.Paris (1881-1883) .Prof. Chem., Ecole de Physique et de Chimie Industrielles (1888-1925)[47] .Directeur des essays, Mint (1907)[48]	(1879)[46]	.Jecker Prize (1890, 1899) .Buignet Prize, Acad.Med. (1893)	-----
WASSERMANN	.Préparateur, FML (1880 1881)	-----	-----	-----
NORTON	.Chemist and Manager, Compagnie Générale des Cyanures, Paris (1878 1883)[50]	-----[49]	-----	-----
VARENNE	?	?	?	?
FAUCONNIER	Préparateur, FML (1881-1884) .Chef de travaux pratiques, Bio.Chem.Lab., Fac.Med.Paris (1888 1893)	-----	-----	-----
GUEBHARD	Préparateur, Medical Physics Lab., Fac.Med.	-----	-----	-------

46 His thesis was entitled Dérivés de la glycérine, (Paris,1879).

47 He succeeded Silva when the latter died. Like Silva Hanriot also lectured on analytical chemistry.

48 He succeeded Riche a former élève of Cahours.

49 He obtained his doctorate in Germany. (See subsequent TABLES)

50 Together with his friend Tcherniak he helped to create a new branch of industrial chemistry, notably the synthesis of thiocyanates and their transformation into ferrocyanides. After the company closed down he left France and like Tcherniak he developed his career abroad. See next tables.

	Paris (1879-1880)[51] .Chef de travaux prati ques, Med.Phy.Lab., Fac.Med. Paris (1883-1888)			
ADAM	. Grimaux's préparateur, Sorbonne (1877 1879) and FML (1879 1881) .Prof. of Chem., Ecole Vétérinaire, Alfort (1888) .Director of the Etablis sements classés de la Seine (1898)	[1887][52]	.Jecker Prize (1893)	-----
POUCHET	.Préparateur, Hygiene course, Fac.Med.Paris (1878)[55] .Préparateur, FML (1880 1881) .Sub director, laboratory of skin diseases, Saint Louis Hospital,Paris (1882 1889) .Expert on Legal Med. and Toxiclogy for the Tribunals (1882) .Agrégé, Pharmacology, Fac.Med.Paris (1883) .Prof. of Pharmacology (1892 1922) .Dean of the Fac. Med. Paris (1916)	(1880)[53]	.Honorary Mention, Prix Bréant,Acad. Sci. (1885)	-------[54]
BROGNIART	Préparateur adjoint, FML (1880 1881)	-----	-----	-------

[51] The Professor responsible for this chair was Gavarret and later Gariel.

[52] His thesis although not supervised by Wurtz was entitled Action de quelques chlorures organiques sur la diphéenyle en présence du chlorure d'aluminium., (Paris, 1887).

[53] His thesis was entitled Contribution à l'étude des matières extractives de l'urine, (Paris,1880)

[54] Although not member of the Académie des Sciences Pouchet was a member of the Académie de Médecine and of other scientific French societies devoted to medicine and hygiene as well as a corresponding member of several foreign academies and scientific societies.

[55] The Professor to whom he was responsible was Bouchardat.

TABLE IV- CAREERS OF THE FRENCH ELEVES AND OF FOREIGN ELEVES RESIDING IN FRANCE OVER A LONG PERIOD

DIETZ	.Préparateur adjoint, FML (1880-1881)	----	----	----
DUBOIS	.Préparateur adjoint, FML, (1880 1881)	----	----	----
GRINER	.Wurtz's private préparateur, Sorbonne (1882? 1884)	----	----	----
COMBES	.Préparateur, FML (1884-1886) .Wurtz's private préparateur, Sorbonne (1884)[57] .Maître de conférences, Sorbonne, (1894)[58]	[1887][56]	.Jecker Prize (1889)	----
FERNBACH	Prof.Bio.Chem.,Paris (?)	[1890][59]	?	----
ETARD	.Chemist, Faïencerie Boulanger, Choisy le-Roi (?) .Préparateur,FML (1880-1884) .Répétiteur adjoint Ec. Polyt(1882-1884) .Répétiteur, Ec. Polyt. (after 1884) Prof.Chem. Ec.Phys. Chim. Industrielles(after 1885) .Examinateur de sortie, Ec. Polyt (1899)	[1880][60]	Jecker Prize (1883)	----

56 His thesis although not under Wurtz's supervision was entitled Nouvelle réaction du chlorure d'aluminium, synthèse de la série grasse, (Paris, 1887). The theses that follow were not under Wurtz's supervision.

57 He succeeded Griner.

58 In this post he succeeded Salet when the latter died in 1894.

59 His thesis was entitled Recherches sur la sucrate, diastase inversive du sucre de canne, (Sceaux, 1890).

60 The title was Recherches sur le rôle oxydant de l'acide chlorochromique, (Paris,1880) and it had been supervised by Cahours..

	.Chef de Service, Institut Pasteur (after 1901)			
DEMARÇAY	.Préparateur,répétiteur, Ec.Polyt. (1872s-1884) .Private researcher[62]	[1880][61]	.Jecker Prize (1880)	Member (1881)
RICHET	.Medical doctor in Hospitals,Paris .Prof. of Physiology Fac.Med.Paris (1887)	[1878][63]	.Nobel Prize Physiology (1913)	Member (1914)

61 His dissertation was entitled Sur les acides tétriques et oxytétriques et leurs homologues, (Paris, 1880). Also under Cahours supervision.

62 His private laboratory acquired a great prestige and was used by Pierre Curie in his research on radium.

63 The title was Des propriétés chimiques et physiologiques du suc gastrique chez l'homme et chez les animaux., (Paris, 1878).

TABLE V- CHARACTERISTICS OF THE "HARD-NUCLEUS"

..NAMES	RELIGION/ CULTURE	BACKGROUND	SOCIAL RELATIONS KINSHIP	CULTURAL INTERESTS	OTHER Features
CAVENTOU (Academic Wing)	?	Family: academics Education:Lyceé, Fac.Med.Paris	Soc.rel.: Willm Girard	?	----
SCHEURER-KESTNER (Industrial Wing)	Freethinker Protestant culture	.Alsatian (Mulhouse .Family: industrial. .Education: Gymn. Strasbourg[2]	Soc.rel.:Lauth[1], Friedel,	.Languages .Travel	Repub.an. (liberal) .Soc./pol. reformer[3] .Dreyfus case.[4] .Critical of Scientific establish.[5]
de CLERMONT (Academic wing)	Protest.Religion Protest.culture	Family: industrial. Education: lycée, Sorbonne, courses in Germany (literary scientific)	Soc.rel.: Friedel Silva Kinship: Friedel[7]	Languages Travel[6] Literature	?
FRIEDEL (Academic Wing)	Protest. Religion Protest.culture	.Alsatian Family: academics[9]	Soc.rel.: Silva,de Clermont, Lauth,	Languages Travel	Repub.an[8]

---

1 In addition to their friendship Lauth and Kestner families were linked by industrial interests, the Usines Scheurer Lauth C.ie. (Thann, Alsace).

2 Among his teachers was T. Kreiss, Wurtz's uncle.

3 He was linked to Gambetta, and was a member of several Parlamentary commissions, but with his liberal views he was against state ultra protectionism.

4 Together with Grimaux, he was involved in the Dreyfus case. Both represented a certain type of politicised intellectuals, especially typical after the 1870s. ORY, P.; SIRINELLI, J.F., Les intellectuels en France de l'affaire Dreyfus à nos jours, (Paris,1986)

5 He did not conform to the implicit rules of the French scientific establishment. He found humiliating the procedures involved both in civic awards like the Légion d'Honneur or in scientific ones as election to the Académie des Sciences.

6 He travelled especially in England and Germany, where he maintained friendly relations notably with Hofmann, Roscoe, Ramsay and Wöhler, and translated some of Wöhler's work into French

7 His wife, a member of the Peugeot family was related to Friedel's first wife, a lady belonging to the Koechlin a Protestant family of industrialists of Mulhouse (Alsace)

8 However he never engaged in active political life.

9 He was grandson of Duvernoy, Prof. of Zoology at the Muséum and son-in law (through his second marriage)of Charles Combes, engineer and Director of the Ecole des Mines.Both were among the first foreign members of the British Association for the Advancement of Science, and later founders of the Association Française pour l'Avancement des Sciences. He was also uncle of a A. Combes.

TABLE V- CHARACTERISTCS OF THE "HARD-NUCLEUS"

		Bank owners Education:Gymn., Univ. Strasb., Sorb.	Le Bel[10] Kinship: de Cler- mont, A. Combes	Music, Art[11]	
NAQUET (Academic Wing)	.Protest. Religion (?) .Protest.culture(?)	Family:(?) Education:(?), Fac. Med. Paris	Soc. rel.: Hanriot Willm, Grimaux[12]	Languages Travel .Political writings	.Socialist Propaganda of atomic theory
LAUTH (Industrial wing)	Protest. Relig. (?) Protestant culture	Alsatian Family: industrial., - academics Education: Gymn. Univ. Strasb.	Soc.rel.: Scheurer Kestner, Grimaux Friedel	Languages Travel Fine-arts[13]	Republ.an (liberal) Soc.Reform.
WILLM (Academic Wing)	Protest. Relig. (?) Protest.culture	Alsatian Family: (?) Education: Gymn. Univ. Strasb.(?)	Soc.rela.: Caven- tou, Girard, Naquet	Languages Travel (?)	?
SILVA (Academic Wing)	Catholic (?) Catholic culture	.Family: administ. academician[15] .Education: informal, Sorbonne[18]	Soc.rel: Friedel, de Clermont, Crafts	Languages[14] Literature Travel[17]	Unconvent. past[16]
GAUTIER (Academic Wing)	——[19]	Family: medical doctors	Soc.Rel.: Caze- neuve, Etard,	?	Republ.an

[10] He was particularly close to Le Bel and Lauth and to Silva, whom he protected. Together with Wurtz and Lauth they used to attend regularly a Parisian gymnasium where they practiced physical exercise and dicussed politics.

[11] He had a strong artistic facet regarding music and art, which he especially revealed in his many drawings from nature.

[12] He intoduced Gerhardt to Grimaux theory and enthused him to follow a scientific career.

[13] Due to his interest in fine arts he developed new colours for porcelain, which motivated his appointment to Sèvres Manufactures. Before leaving this post he created there a school for designers and painters.

[14] He learned French, English and German and he liked literature, wich he used to read in the original language.

[15] He was a mulatto from a family with serious financial problems. His grandfather had been an administrator of Cabo Verde Islands (at the time a Portuguese colony) and corresponding member of the Academia Real das Ciências de Lisboa.

[16] He had been an apprentice of pharmacy in Lisbon and established a private pharmacy in Macau (a Portuguese colony in China). During an epidemic Silva helped the French fleet at the time carrying out an expedition in China His contacts with French doctors and pharmacists fostered his decision to go to France.

[17] He especially travelled in England and Germany . In 1881-1882 Dumas entrusted him with an official visit to foregn teaching laboratories in Sweden, Denmark, England and Germany. His Report which was meant to emphasise teaching aspects complemented Wurtz's reports on foreign laboratories which focussed on research. See SILVA, R.D. "Les laboratoires et l'enseignement pratique de la chimie", Ann.Chim., 27 [5] (1882), 567-574.

[18] Given his decision to stay in France, Silva had to go through the different stages of a French formal education as was required. So far, he and presumably the other Protuguese élève Lourenço were the only foreign élèves who did so.

[19] Although his religious affiliation is unknown he seems to have been a freethinker. However he later adhered to some iniatives of the hard-nucleous rooted in Protestant culture (See subsequent TABLE)

TABLE V- CHARACTERISTICS OF THE "HARD-NUCLEUS"

		Education: lycée, Fac. Med. Mont pellier	Hanriot, Richet		
SALET (Academic Wing)	Protest.Relig..(?) Protestculture	Family : architects Education: lycée, Sorbonne England [20]	Soc.rel: Friedel, Griner, Henninger Lauth, Combes Pabst, Le Bel [23]	Languages Music Art[21] Popularisation of science	.Partially rejected[22] by the academic establish.
GRIMAUX (Academic Wing)	Protest.Culture[24]	Family: modest working class, navy Education: lycée, Navy (pharmacy), Fac. Med.Paris	Soc.rel.: Naquet, Lauth, Friedel, Adam	.Playwriting, novels .History of Science.	.Unconven. past[25] .Propagand. of atomic theory Republican .Dreyfus case
HENNINGER (Academic Wing)	Protest Rel. (?) Protestant culture	Family: (?) Education: German Gymnasium, Fac.Med.Paris	Soc. rel.: Le Bel, Tollens, Vogt, Combes, Girard, Griner,Darms-täedter,Hanriot	Language Travel	.Anti Prussia
LE BEL (Industrial Wing)	Protest. Relig. (?) Protest.culture	Alsatian Family: industrial., academics .Education: Gymn. Strasb., Ec. Polyt	Soc.rel.: Friedel, Henninger, Green	Languages Travel Philosophy Paleontology Botany	.Intolerant of bureaucracy and official-dom .Caustic wit
HANRIOT (Academic wing)	-----	Family: Rural lawyers Education: lycée, Fac. Med. Paris	Soc. rel.: Richet, Gautier, Henninger Willm	?	---
COMBES	.Protest Relig.(?)	Family: lawyers and	Soc.rel.:Lauth	.Languages	

20 Although having attended a lycée Salet had a private tutor, who fostered his interests in music, literature and art. Before starting his career he came to England and attended Williamson's laboratory.

21 He especially cultivated drawing skills and design, which he used in devising new instruments and technical apparatus.

22 He was blamed for devoting too much time to his artistic activities, which were considered exaggerated and for his later almost exclusive interests in technical applications and in new areas where physics and chemistry overlap, notably spectroscopy.

23 In his youth Salet had been influenced by Le Bel's uncle Boussingault, who regularly visited his parents house.

24 Grimaux married very young a Protestant girl, whose father was a Protestant Republican with persecutions in his family background. He very much influenced him, as Grimaux often acknowledged. He was involved in initiatives of the hard nucleus related to Protestant tradition,(see next Table).

25 His youth was passed among sailors who often engaged in lively political discussions.

TABLE V- CHARACTERISTICS OF THE "HARD-NUCLEUS"

(Academic Wing)	.Protest. culture	academics .Education:lycée, Ec. Polytech.	Henninger, Salet Girard, Pabst, Le Bel,Griner Kinship: Friedel	Travel Music[26]	

[26] He was popular in Parisian musical circles and used to go to Bayreuth as an admirer of Wagner.

TABLE VI- SPECIFIC ACTIVITIES OF THE 'HARD-NUCLEUS'

	EDUCATIONAL INSTITUTIONS		PUBLICATIONS	OTHER ACTIVITIES
NAMES	ECOLE ALSACIENNE (Found. 1871)	ECOLE de PHYSIQUE et de CHIMIE INDUS-TRIELLES (Found. 1882)	TEXT BOOKS HISTORY OF SCIENCE POPULARISATION	EXHIBITIONS MEETINGS
CAVENTOU	---- -	------	-----	----
SCHEURER-KESTNER	-----[1]		Principes de la théorie des types, (Paris, 1862) Pouvoir calorifique des combustibles solides, liquides et solides, (Paris, 1896) Several articles on popularisation in: Bull.Soc.Ind. Mulhouse République Française Revue scientifique Revue Alsacienne	Karlsruhe Meet.(1860) President to the comm. to establish an extra class,Un.Exhib(1889) Pres. of the jury of that class, Un.Exhib(1890) Vice-Pres. of the jury of group V,Univ.Exhib. (1890)
de CLERMONT	Founder, share-holder, administrator[2]	------	Translations of foreign textbooks. ?	?
FRIEDEL	Founder, share-holder, administrator	Promoter	Editor of Wurtz's Introduction à l'étude de la chimie, (Paris,1885) (with Salet) Cours de minéralogie professé à la Faculté des Sciences de Paris (Paris, 1893)	Karslruhe Meet. (1860) Member of the jury, Univ. Exhib.(1869, 1878, 1889,1900)
NAQUET	-----	------	Principes de chimie fondés sur les théories modernes, (Paris, 1865)[3]	?

[1] Although he was not directly involved, several members of his family and also one of his companies, Maison Scheurer- Rott (Thann, Alsace) were shareholders.

[2] The administration of the Ecole Alsacienne was also responsible for the curriculum and methods of teaching

[3] Partington claimed that Naquet's book was the first text-book to adovocate Gerhardt's type theory, which is not correct since Wurtz's text book Leçons de philosophie chimique published in 1864 was already completly based on that framework. Naquet's book mentioned and praised Wurtz's work and was translated into English and German. The German translation was carried out by another élève of Wurtz, Eugene Sell. See PARTINGTON, A History of Chemistry, (London, 1964), vol.4,p.424.

[4] It was while he held the post of Vice president of the Parisian municipal council that he finally succeeded in getting official support for the foundation of this institution. The idea of founding this technical school had been the result of a report following the Universal Exhibition of 1878 in which Lauth expressed his views on what he believed to be the inferiority of French industry. During its first years the directorship of the Ecole

			Les principes de chimie, (Paris, 1882-1889) (with Hanriot)	
LAUTH	Shareholder	Promoter, founder[4] director (1898-1905)	Collaborator of the Agenda du Chimiste (after 1877) Les produits chimiques à l'Exposition de 1878 (Paris, 1878) La Manufacture nationale de Sèvres,1879-1887, (Paris, 1887)	Report in the section of chemicals, Univ. Exhibition (1878)
WILLM	-----	-----	Traité de chimie minérale et organique comprenant la chimie pure et appliquée, (Paris, 1888) (with Hanriot)	?
SILVA	-----	Professor(from1881)		Portuguese representat in the Jury of the Univ. Exhibition (1878)
GAUTIER	Founder, share-holder, administrator	-----	.Sur la sophistication et l'analyse des vins (Paris, 1876) Le cuivre et le plomb dans l'alimentation et l'industrie au point de vue de l'higiène, (Paris,1883)	Karlsruhe Meet.(1860)[5] ?
SALET	Shareholder	-----	.Creator and editor of the Agenda du Chimiste (1877-1894) Editor of Wurtz's Introduction à l'étude de la chimie, (Paris, 1885) .Several articles for populari-sation in Journal de physique (edit. d'Almeida) and in	

Municipale was held successively by three Alsatians: the first director was Schutzenberger, followed by Lauth and Haller.

[5] At the time he was working in Montpellier's University and was not yet carrying out research at Wurtz's laboratory.

			The Laboratory[6] Traité élémentaire de spectroscopie, (Paris,1888)[7]	
GRIMAUX	----	----	Traité de chimie organique élémentaire (Paris,1872)[8] .Théories et notations chi miques, (Paris, 1883) .Many articles on history of Science and the books: Oeuvres de Lavoisier, vols. 5 and 6 (Paris,1892-1893) .Lavoisier, 1743-1794, Paris,1899) .Charles Gerhardt, sa vie, son oeuvre, sa correspondance, 1816 1856, (Paris,1900) (with C.Gerhardt's son) .Several articles for popula-risation of chemistry and its relations with industry.	?
HENNINGER	----	Professor (1882)	Collaborator of the Agenda du Chimiste (from 1877)	?
LE BEL	----	----	Collaborator of the Agenda du chimiste	?
HANRIOT	----	Founder Professor (1888-1925)	Les principes de chimie, (Paris,1882 1889) (with Naquet) Traité de chimie minérale et organique comprenant la chi mie pure et appliquée (Paris, 1888) (with Willm)[9] Les eaux minérales de l'Al gérie, (Paris,1910)	.Secretary (1889),Vice-president (1900) of the International Comm. of the Chemistry Cong. Member of the jury of admission, Univ.Exhib. (1900)

[6] As a collaborator of the British journal The Laboratory, Salet published many of the lectures and seminars held in Wurtz's laboratory by several of his élèves, and French and foreign guests. This may have contributed to publicize the activities of the école. Other of his articles published in these journals such as those about Faraday's law and on coefficients of expansion of gases were included in several books, as for instance in Naumman's Chimie physique (1877).

[7] Salet's work in spectroscopy was acknowledged notably by Lockyer in his articles and in his book Studies in Spectrum Analysis, (London, 1878)

[8] He also wrote the introductions of other authors' books such as the French translation of a book of Wurtz's Russian élève Alexeev, Méthode de transformation des combinaisons organiques, (Paris,1891)

[9] He also collaborated in Richet's dictionary of physiology.

COMBES	------	------	Responsible for the sections on chemistry and minaralogy in Revue des travaux scientifiques (from1882)[10] .Collaborator of the Agenda du Chimiste (1892-1893) .Chief-editor of the Agenda du chimiste (after1894)[11] .Responsible for the sections of chemistry and mineralogy in Revue des travaux scientifiques (after 1882)	

[10] This journal was published by the Comité des Travaux Scientifiques et Historiques under the auspicies of the ministry of Education.

[11] Like his predecessor Salet he had the cooperation of Wurtz's élèves, Girard, Pabst and Griner

TABLE VII- CHARACTERISTICS OF VISITING FOREIGN ELEVES

NAMES	BACKGROUND	RESEARCH TRAINING	FURTHER POSTS	FURTHER ECOLES	CULTURAL INTERESTS
LUNA	?	?	Prof.Chem., Univ. Madrid (before1852)	?	?
MARCET	Family: Medical Doctors[1],Academics Education: Geneva, Grad. Medicine, Univ. Edinburgh (1850)	----	.Assistant Phy-sician, West-minster Hospital, .London (1850) Physician, Com-sumption Hosp., Brompton (1850) .Examiner, Royal College of Physicians (1867)	----	Languages Travel
PERROT	?	Doctor., Fac Med. Paris (1861)	Geneva(from 1863)	----	Languages Travel
MOSCHNIN	?	?	?	?	?
BUTLEROV	Family: Army officers, land owners[2] Education:private boarding school, Gymn. Kazan, Grad. Univ. Kazan (Claus, Zinin)[5] (1849)	Thesis, Univ.Kazan (1851) Doctorate, Univ. Moscow (1854) German Univs., (Kékulé, Erlen-meyer) (1857-1858)	Part-time lecturer Univ. Kazan (1849-1850) .Claus's assistant Univ.Kazan (1850 1852) .Rector, Univ. Ka-zan(1860 1863) .Prof. chem., Univ St Petersburg (1868 1885)[6]	Univ. Kazan Univ. St Peters-burg	Languages Travel Entomology[3] Spriritualism[4]

[1] His grandmother was Jane Marcet whose book Conversations on chemistry influenced Faraday to follow a scientific career. His grand-father Alexander Marcet of Swiss origin was a physician and later Prof. of chemistry at Guy's Hospital, London. Their social circle included Berzelius, H. Davy, the botanist Augustin de Candolle, the mathematician H. B. de Saussure, the economist Malthus, the chemist Marc Auguste Pictet and the writers Harriet Martineau and Maria Edgeworth, among others. See LINDEE, S. "The American Career of Jane Marcet's Conversations on Chemistry", Isis, 82 (1991), 8 23.

[2] His mother's family owned part of his home village Butlerovka.

[3] Especially apiculture.which he popularised and contributed to organise as a scientific field in Russia.

[4] He wanted to apply scientific methods to the study of "medium" phenomena which became very common in the late 19th century as a result of the tensions between religion and science.Identical attitudes were assumed for instance by Sir Oliver Lodge in England and Richet in France, who collaborated in these studies with the writer Arthur Conan Doyle.

[5] Zinin was one of the first champions of Gerhardt's ideas in Russia.

[6] He was succeeded by Menschutkin, who adopting a more positivistic posture, did not accept initially

TABLE VII- CHARACTERISTICS OF VISITING FOREIGN <u>ELEVES</u>

-COUPER	Family: textile industrialists Education: educated by private teachers .Language studies, Germany (1851) .Glasgow Univ. (Latin, Greek cour-ses) (1851-1852) .Studies in Germa-ny (Summer1852) .Edinburgh Univ. (Philosophy,Lan-guages)[7] (1852-1853)	Berlin , Chem. (Sonnenschein, Rammelsberg) and Physics (1854-1856)	------ (Invalid due to mental illness)	-----	Languages Travel Literature Philosophy
LIEBEN	Family:Wealthy merchants Education: educated by private teachers[8]	Vienna, Heidel-berg Doctor., Heidel-berg (1855)	.Privatdoz.., Univ. Vienna (1865) .ProfChem.,Univ. Palermo (1865-1867) .ProfChem.,Univ Turin (1867-1871) ProfChem.,Univ Prague (1871-1875) .ProfChem.,Univ (from 1875)	Vienna	Languages Travel Literature Music
SIMPSON	Family: (?) Education: private school; Trinity College,Dublin;	.Graham's lab.,-Univ. College, London (1843-1845) . Dumas's lectures Paris (1845) .Heidelberg (Bun-sen), Marburg (Kolbe) (1851-1854)	Lecturer Chem., Park Street Medi-cal Sch. (1847-1857) .Private researcher Dublin(1860-1867) .Prof. Chem., Queen's College, Cork, Dublin, (1872-1891)	?	Languages Travel Literature
FRAPPOLI	Family: (?)	?	Prof. Chem.,Univ.	?	?

Butlerov's structural approach. However, after some discussion Menschutkin later changed his position.

[7] After attending the courses of Sir William Hamilton (Logic and Metaphysics) and of Prof. McDougal (moral philosophy) Couper visited Italy, Germany and Austria with his friend Alexander Hamilton, later a Presbyterian minister.

[8] Even in childhood Lieben could hardly conform with the discipline of a school..

ATKINSON	Education: (?) Family: (?) Education: (?)	Doctor., Göttingen (Wöhler) (c.1856)	Milano (?) Prof. Physics, Royal Military College, Sandhurst(from 1862)	-----	Languages Travel Popularisation of Science[9]
FOSTER	Family: Calico printers,magistrates Education: Private schools, Grad. Univ. College, London (1855)	Ghent (Kékulé) (1858-1860?) Heidelberg (1860?)	.Assitant(Williamson),Univ.Coll., London (1855-1858?) .Prof. Nat. Phil., Andersonian Inst. Glasgow (1862) .Prof. Phys.,Univ (1865-1898) .Principal,Univ. Coll. (1900-1904)	London	Languages Travel Popularisation of Science Pedagogy[10]
BEILSTEIN	Family: weavers, tailors[11], related to Liebig Education: German education (?)	Heidelberg (Bunsen, Kékulé), Münich (Liebig), Göttingen (Wöhler) Doctorate, Göttingen (1858)	.Privatdoz..(1862) Ext.Prof. (1865), Göttingen .Prof., Tech.Inst., St. Petersburg (1866)	St. Petersburg	Travel Languages Amat.-musician[12] Amat.of fine-arts
LOURENÇO	Family: (?) Education: Grad., Escola Médico-Cirúrgica, Goa (?)	Heidelberg (Bunsen) England (1861-1862)	Prof. Chem., Escola Politécnica, Lisbon (from 1863)	----	Languages Travel
SAWITSCH	Family: (?) Education: Grad., Univ. Kazan (Butlerov) (before 1860)	?	Prof. Univ. Kharkov (c.1860)	----	Languages Travel
BAUER	Family: (?) Education:(?)	German Univ. (Liebig) (before 1860)	.Assistant, Vienna Handelsacademie (Prof.Schrötter)	ViennaHandelsacademie	Languages Travel History of Science

9 He used to deliver public lectures and notably translated Ganot's Eléments de physique and published Popular lectures on scientific subjects, (London, 1893). He also published jointly with G.Carey Foster on applied physics.

10 He was especially concerned with the methods for teaching laboratory practice in physics. He advocated the idea that precise measurements should be inculcated in students as the most important means of advancing science.

11 His father was a tailor and his uncle (from his mother side),who was related to Liebig,was a court tailor of the czar. Beilstein was sent by his uncle to study in Germany.

12 He was considerably renowned at the time as a musician.

TABLE VII- CHARACTERISTICS OF VISITING FOREIGN ELEVES

		Doctor. (?)	(c.1861) .Prof.Chem.Techn. Wien Handels. (1869) .Prof.Chem., Wien Handels. (1876)		(he published numerous articles)
MACHUCA	Family: (?) Education: (?)	?	?	?	?
ALEXEEV	Family: ? Education: Grad., Univ. Kazan (Butlerov) (c.1860)	Tübingen (Strecker)(before 1862) Doctor. (?)	Prof.chem. Univ. Kiev (from1868)	?	Languages(transl. chem.textbooks) Travel ?
OSER	Family : (?) Education: (?)	Doctor. (?) (?)	.Prof. Chem., Techn. Agricult. Vienna (from 1876)	?	?
SCHIFF	Family: Academics Education: (?)	Doctor., Göttingen (Wöhler) (1857)	.Privatdoz. Univ. Berne[13] (1857) . Prof. Chem., Univ.Pisa (?) .Prof. Chem.,Mus. di Storia Naturale, Florence(1863) .Prof. Chem., Univ.Turino, (1877) .Prof. Chem., Inst. di Studi Superiori, Florence (from 1879)	Florence	Languages Travel Literature Classical studies History History of Science (some publicat.)
OPPENHEIM	Family: (?) Education: (?)	Bonn, Göttingen, Heidelberg (1852 1857) London (Williamson) (1857-1861)	Privatdoz., Univ. Berlin (1868-1873) .Prof. Chem., Univ. Berlin (1873-1877) .Prof.Chem.,Acad. Münster (1877)	?	Languages Travel History of Science
CRAFTS	Family: Woolen manufacturers Education: Engi	Heidelberg (Bunsen) (1860-1862)	Prof. Chem., MIT (1870) Return to Europe	------	Languages Travel ?

[13] Due to his liberal political ideas he had to leave Germany and went to Switzerland

	neering and mining (USA, Germany, (Freiberg))		(1874-1891)[14] Prof. Chem. MIT (1891) President MIT (until 1900)		
BOLTON	Family: Medical Doctors[15] Education: Grad., Columbia Univ. (1862)	Heidelberg (Bunsen),Berlin (Hofmann), Göttingen (Wöhler) (1863 1866) Doct, Göttingen (1866)	Private researcher, N. York (1866-1872) Assistant, Columbia Univ. (from 1872) Prof. chem., Woman's Medical College,N.York (from1875) Prof.Chem.,Trinity College (1877-1887), N.York	----	Languages Travel Bibliographer[16] Folklorist(rhymes and fairy tales) History of Science (alchemy,Priestley's scientific correspondence)
MICHAELSON	Family: (?) Education:(?)	Doctorate, Univ. Upsala (?)	Assitant, Univ. Uppsala (1857-1860)	----	Languages Travel
MENSCHUT-KIN	Family:(?) Education: Grad. Univ.St.Petersburg (Sokolov, Voskresenski)	Tübingen (Strecker)(before 1864) Marburg (Kolbe) (1865) MSc., Univ. St. Petersburg (1865) Doct., Univ St. Petersburg (1885?)	Privatdoz., Univ. St.Petersb.(1866)[17] Prof.Anal. Chem., Univ.St.Petersburg (1876) Prof.Org.Chem. Univ. St.Petersburg (1885-1902) Prof.Anal.and Org Chem., Polytech. Inst.,St. Petersburg (from1902)	?	Languages Travel Musician (Founder of the orchestra and choir of St. Petersburg Univ.)
ZAYTSEV	Family: Tea merchants Education: Grad.	Marburg (Kolbe) (before 1864) Doctorate,Leipzig	Prof.,Univ. Kazan (from 1865)[17]	Kazan	Languages Travel ?

[14] He came to Europe due to health reasons and during this period he worked with Friedel at the Ecole des Mines.

[15] Notably his grand father pioneered vaccination in the United States.

[16] He published Catalogue of Scientific and Technical Periodicals, 1865 1882 and in 1893 Select Bibliography of Chemistry. He was chairman of the Committee on the bibliography of chemistry of the American Chemical Society

[17] In 1869 Menschutkin represented Mendeleev, who was unable to attend due to illness, at a session of the Russian Chemical Society in which he presented the periodic law underlying the periodic table.

	Univ.Kazan (Butlerov) (?)	(1866)			
MAYER	?	?	?	?	?
LAUTEMANN	?	?	?	?	?
LIPPMANN	Family: (?) Education: Grad. Tech.Hochschule Wien (?)	Doctor., Heidel-berg (1864)	Prof.Chem., Univ. Vienna (1875-1919) .Privatdoz.,Tech. Hochsch., Vienna (1875-1919)	?	Languages Travel
PFAUNDLER	Family:(?) Education: (?)	Doctor., Univ. Innsbruck (1861) .Münich, Inns-bruck (1857-1864?)	Privatdoz.,Univ. Innsbruck (1865-1867) .Prof. Phys.,Univ. Innsbruck(1867-1881) .Rector, Univ. Innsbruck (1881 1891) .Prof.Phys.,Univ. Graz (from1891)	Innsbruck	Languages Travel Pedagogy
SELL	Family: (?) Education:Grad.. Univ. Bonn (1861)	.London, Royal Coll. Chem. (Hof mann) (1861-1863) .Doctor.,Univ. Bonn (1863) .Heidelberg (Bun-sen) (bef.1865)	Assistant (Hof-mann), Univ. Ber-lin (c.1866-1869) .Privat Doc., Univ Berlin (1869-1875) Prof.Chem,Univ. Berlin (from1875) .Empire's councill. for hygiene (1877) Hon. Prof., Univ. Berlin (?)	Berlin	Languages (transl. of chem. textbooks) Travel ?
LUGUININ	Family : Army officers Education: Grad., Mikhailovskoye Artillery School Moscow (?)	.Poytech. Sch. Zürich (Wislice nus) (1864) .Regnault's lab., Paris (1865-1866) .Collège de Fran-	Assistant, Scient. Secretary,Military Scient. Comm. (befo.1863) .Exile, Crimea (1866-1869)[19]	Moscow	Languages Travel Politics

[18] He succeeded Markovnikov, another élève of Butlerov.

[19] While in western Europe he met Russian political exiles like Herzen and Bakunin and these relations were partly the cause of his exile.

	Lecture courses in in Phys. and Chem. Heidelberg,Zürich (1863-1864)	ce (Berthelot), Paris (1869-1877)	. Organiser and Director Thermo-chemical Lab., Univ. Moscow (1877-1905)		
LEVERKUS	?	?	?	?	?
CLEVE	Family: (?) Education : Grad. Univ.Upsala (1860)	Doctor. Univ. Upsala (Svanberg) (1863) England, Italy, Switzerland (1866 -1867)	Assistant, Techn. Instit. Stockholm (1870-1882) Prof.Chem. Univ. Upsala (from 1882) Nobel Prize Commissioner, Chem. (1904)	Stockholm Upsala	Languages Travel (?)
LADENBURG	Family: (?) Education: Grad. Karlsruhe Polytech (bef.1860)	.Heidelberg (Bunsen, Kirchoff, Carius (1860-1862) .Berlin(1862-1865) .Ghent (Kékulé) (1865-1866)	.Privatdoz., Heidelberg (1868-1872) Prof.Chem.,Univ. Kiel (1872-1889) .Prof.Chem.,Univ. Breslau (1889-1903)	?	Languages Travel History of Science Popularisation of Science
WHEELER	?	?	?	?	?
BUCHANAN	Family: Members of Parliament Education:Glasgow High Sch.;Grad. Univ.Glasgow (1863)	Marburg, Bonn, Leipzig (1863-1867)	Assistant (Crum Brown), Univ. Edinburgh (1868) .Oceanographic mission,<u>Challenger</u>(1871-1876[20] .Private research[21], several voyages (from1876) .Commissioner for the establishment of Ben Nevis Obs. and Scottish	?	Languages Travel Natural Science Geography

[20] He was appointed by the Circumnavigation Committee of the Royal Society to be responsible for matters concerning physics, chemistry and geology during the oceanographic mission of the <u>Challenger</u>. The choice for this post was based on Buchanan's reputation as a chemist, but also on his ability to devise and making apparatus.

[21] He established a private laboratory in Edinburgh and made also several investigations on the west coast of Scotland and on the Great Glen lochs in his private steam yacht, the <u>Mallard</u>. He engaged in several voyages of the cable laying ships across the Atlantic.

			Marine Station .Lecturer Geography, Univ. Cambridge (1889-1893) .Administrator, Oceanograp.Inst Paris[22]		
PICTET, R.	Family:Academics Education: Grad. Univ. Geneva (bef.1868)	?	Prof.Indust.Phys. Univ.Geneva (from 1879)[23]	?	?
TOLLENS	Family: (?) Education:	German Univ. (Fitig) (c.1864)	Prof. Agric.Chem. Göttingen (1873-1911)	Göttingen	Languages Travel
DARM-STÄEDTER	Family : (?) Education: Grad. Univ. Heidelberg, (1865-1867?)	Doctor. Univ. Heidelberg,(1868) Leipzig(1868-1869),Berlin (1869)	Prof. Chem. Univ.Berlin (?)	?	Languages Travel (?)
DOBROS_LAVIN	Family : (?) Education: (?)	German Univ. (bef. 1870)	?	?	Languages Travel (?)
FRANCHI-MONT	Family: (?) Education: Grad. Univ. Leiden (1868 ? 1870)	.Doctor., Univ. Leyden (1871) .Bonn (1871)	Assistant (Kékulé), Univ. Bonn (1872) Prof. Chem.,Univ. Leyden (1889-1900)	Leiden ??	Languages Travel (?)
VAN'T HOFF	Family: Medical doctors, Wine dealers Education: private sch. (Gymnasium like) (?); Hoogere Burgerschool (Ger-	. Bonn (Kékulé) (1872 1873) .Doctor., Univ. Utrecht (1874)	.Assistant. Phys., Veterinary Sch., Utrecht (1876) .Prof. Theor.Chem. Phys., Univ. Amsterdam (1877) .Prof. Chem., Min.	Amsterdam	Languages Travel Literature (Burns, Heine, Byron) Poetry writing Philosophy (Comte Taine, Whewell)

22 This Institute was founded by Prince Albert I of Monaco,with whom he had a friendly relationship.

23 After his visit to the University of Geneva Berthelot made the followig comment on Pictet:

> Nous avons vu à Paris ce dernier savant [Pictet], homme singulier, plein de jeunesse, d'ardeur et d'initiative, inventeur partagé entre la théorie pure, qu'il entend à sa façon et les applications industrielles; c'est un mélange de Français et d'Américain, qui n'a pas dit son dernier mot.

BERTHELOT, Science et Philosophie, (Paris, 1886), p.337.

	man Real schule like) (1828); Polytech.Sch., Delft(1869); Univ. Leyden (1871-1872)		Geol.,Univ. Amst. (1878-1895) .Prof. Chem. Univ.Berlin (from 1896)		Natural Science (Entomology) Music (singer and piano player)
BASAROV	Family: (?) Education:(?)	.Doctor., Univ. Leipzig (1868)	Prof., Univ. Kiev (1871-1883) . Director of the service of aclimatisation and viticulture, Yalta (from 1883)	?	Languages Travel
TCHERNIAK	Family: (?) wealthy family of Kiev. Education: (?)[24]	Zürich Polytech. (Victor Meyer) (1873)[25] Doctor., Univ. Zürich (1874) Heidelberg (Bunsen) (1874)	Private researcher, Freiburg (from 1888) and consultant of Fabriques de Produits Chimiques de Thann et Mulhouse [26] and Farbwerke Höchst . Chemist, South Metropolitan Gas Comp.,London (from1903)[27] .Lord Moulton's adviser, High Explosives Dep., War Office ,London (1915) .Chemist, Rowntree & Co., N.York (1916 1927)	In the several laboratories where he worked	Languages Travel Literarture (French, German, English, American) Collector of first editions of British writers
NEVOLE	Family: (?) Education:(?)	German Univ. (before 1870)	?	?	Languages Travel
RAYMAN	Family: (?) Education: Grad., Prague Polytech. (1874)	Bonn (1874-1876) Doctor. Bonn Univ. (1876)	Prof. Chem. ,Pra- Univ. (c.1878-1910)	?	Languages Travel

24 Norton, his close friend and biographer, mentioned that Tcherniak enjoyed an excellent preparatory education.

25 In Meyer's laboratory he met among others the Alsatian Emilio Noelting, later head of the Ecole de Chimie de Mulhouse, Schiff and Wurtz's close friend, the Alsatian E. Kopp.

26 He was entrusted by Scheurer Kestner, a proprietor of this company, with investigations as a consultatnt.

27 His work as a consultatnt of this company followed his research on the recovery of thiocyanates from waste lime initiated in 1901.

TABLE VII- CHARACTERISTICS OF VISITING FOREIGN ELEVES

GREENE	Family: Printing business Education: Grad., Philadelphia High School(1870)	Doctor. Jefferson Medical Sch (1873)	Assistant,Jefferson Medical Sch. (1873-1877) .Demonst. Chem. Jefferson Medical Sch. (1875) .Demonst.,Univ Pennsylvania (1879) .Prof.Chem., Central High Sch. Philadelphia (1882-1890)[28] .Consultant for medical and industrial Chemistry	?	Languages Travel Music Art Pedagogy
WEISGERBER	?	?	?	?	?
PATRY	?	?	?	?	?
NORTON	Family: Clergymen (Presbyterian) Education: Grad. Hamilton College (1873)	German Univ. (Bunsen, Kirchoff) (1873) Doctor., Heidelberg (1875) Berlin (Hofmann) (1875-1878)	.Prof. Chem., Univ. Cincinnati (1883-1900)[29] USA consul, Turkey (1900-1906) . USA government commissioner for the survey on European chemical industry (1910) and Norton's American Dyestuffs census(1914) .Consultant of American Cyanamid Co. (c.1920)	?	Languages Travel (all over Europe and Asia, already in 1873-1877) Scient. journalism Genealogy Oenology
MICHAEL	Family: (?) education: (?)	German Univ.: Berlin, Heidelberg (1878?-1879) Doctor. Boston (1890)	Prof.Chem., Tuft's College, Boston (1894-1907) .Prof. Emeritus,	?	Languages Travel ?

[28] This school was one of the first in USA to introduce laboratory practice in its teaching, thanks to Greene. One of the text books adopted was Greene's translation of Wurtz's Leçons élémentaires de chimie moderne.

[29] Here he took an active part in the social, religious and intellectual life of the community.

			Cambridge Mass. Univ.(1907-1912) .Prof. Chem., Harvard Univ. (1912-1936)		
TATARINOV	?	?	?	?	?
MORLEY	Family: Academics Education: Univ. Coll. School; Grad Univ.Coll., London (Williamson) (1875)	.Bonn (Kékulé) (1878) .Munich (Baeyer) (1879) .Berlin (1881) .Doctor., Univ. Coll., London (1882-1883)	.Assistant (Williamson) Univ. Coll.Lon. (1883-1888) .Prof. Chem., Queen's Coll., London(1888-1901) .Lecturer Chem. and Phys.,Med. Sch.,Charing Cross Hosp.(from 1894)	London (Univ. Coll.)	Languages Travel Pedagogy Bibliographer (Chief-editor of the Royal Society Catalogue of Scientific papers)
WALITZKY	?	?	?	?	?
PICTET, A.	Family: Academics Education: ? Geneva	Dresden, Bonn (1876-1880) .Doctor., Univ, Geneva (1881)	.Privat dozent, Univ. Geneva, (1882-1894)) .Prof. Org. Chem. Univ. Geneva (1894-1899) .Prof. Biol. and Pharm. Chem., Univ. Geneva (from 1899)	?	Languages Travel
PLIMPTON	?	?	.Assistant Chem., Univ. College London (1884) .Lecturer Chem., Middlessex Hosp. Medic. School, London (1893)	?	?
NEWBURY	?	?	?	?	?
ŒCONOMIDES	?	?	?	?	?
HELLON	?	?	?	?	?

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