Chemistry in the 17th Century: Art or Science?

[DRAFT]

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Introduction

In his study of the didactic origins of chemistry Owen Hannaway maintained that in the seventeenth century chemistry achieved 'sufficient coherency and identity to sustain a vigorous and ongoing didactic tradition.'[1] The origins of the debate on the status of alchemy can be traced back to the Middle Ages. Albert the Great (1206-1280) and Roger Bacon (c. 1214-1294) maintained that alchemy was both science and art. Albert wanted to incorporate alchemy within the Aristotelian system of knowledge, while Bacon maintained that it occupied a central position in the experimental science, that, in his view, combined theory and practice.[2] In the sixteenth century, the status of alchemy was rather low. In most Renaissance encyclopaedias alchemy was regarded as practical art, as attested by the *Bibliotheca Universalis* (1545) of Conrad Gessner (1516-1565), by *De subtilitate* (1550) of Girolamo Cardano (1501-1576), and by Theodore Zwinger's (1533-1588) *Theatrum humanae vitae* (1586).[3] When in his *Alchemia* (1597) Libavius endeavoured to make chemistry a distinctive subject of instruction, chemistry was not yet recognised as an independent discipline.

In the sixteenth century chemistry went through a change that brought about significant rupture with the medieval alchemical tradition. Two factors contributed to establish this break, one was the development of practical chemistry, in particular metallurgy; the other was the rise and development of the Paracelsian movement. At the beginning of the sixteenth century two booklets,

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[1] Hannaway 1975, p. ix.

[2] For a survey of the relationship between alchemy and natural philosophy in the middle ages, see Crisciani and Pereira (1996), pp. 31-53.

[3] See Mandosio (1990-1991), pp. 199-282.

namely the *Bergbüchlein* ("The Little book on Ores"), attributed to Calbus, the town physician of Freiberg, and the anonymous *Probierbüchlein* ("The Little Book on Assaying") conveyed into the printed book much of the practical knowledge in the fields of mineralogy, metallurgy and mining, previously transmitted orally or contained in manuscripts.[4] Whereas these two books, as well as other early alchemical books (as for instance the *Alchymia* published at Strassburg in 1539) were mainly collections of receipts, *De la Pyrotechnia* (1540) of Vannoccio Biringuccio (1480-1539) was better organised, more elaborate and more comprehensive.[5] It also contained some theory on the origin of metals, which was based on the philosophy of Aristotle. Biringuccio criticised the practice of secrecy and endeavoured to rationalize the knowledge and practice of mining and metallurgy. Biringuccio's work was followed by Agricola's influential *De re metallica* (1556). By providing a systematic treatment of the subject, Agricola contributed to elevate the status of mineralogy and metallurgy over the traditional role of practical art.[6] A humanist and an Aristotelian, Agricola (1494-1555) criticised the obscure language of the alchemists and contributed to create a coherent technical terminology by giving new names to substances and instruments. Having established clear boundaries between alchemy and metallurgy, Agricola aimed at upgrading the profession of the miner and metallurgist recommending both practical and theoretical apprenticeship, that ought to include natural philosophy. Following Aristotle, Agricola maintained that science was knowledge of causes; so, he claimed, Philosophy would provide the miner with the knowledge of 'origin, cause and nature of subterraneal things' (Agricola, 1950, p. 3).

Agricola's views inspired much of Libavius' project of establishing chemistry as a didactic discipline - though Libavius (unlike Agricola) never ruled out the transmutation of metals. In *The Chemist and the Word* Hannaway pointed out that the reform of terminology was central to Libavius' project to give chemistry a distinct role in the world of learning. (Hannaway 1975, pp. 119-120) In order to achieve his goal, Libavius aimed at giving chemistry organization and logical method. His project was principally meant to eradicate from chemistry the pernicious influence of Paracelsus and his followers. Paracelsus' view of alchemy subverted the traditional classification of knowledge. He saw alchemy (in his view alchemy was not the transmutation of metals) as one of the foundations of medicine. For Paracelsus, art brings nature to perfection, and alchemy, namely 'scientia separationis', or *spagyria* is the key to understand the human body and the natural world.

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[4] Both these books were published anonymously: the *Bergbüchlein* saw the light between 1505 and 1510; the *Probierbüchlein* soon after 1520. For bibliography and texts see Darmstaedter (1926); Sisco and Smith (1949). Agricola (1950), pp. 609-614. For the early printed books of alchemy and chemistry, see Hirsch (1950) and Long (2001), pp. 177- 178.

[5] Biringuccio (1977) and Long (2001), p. 181.

[6] Beretta (1993), pp. 78-93.

Thanks to fire, the chemical physicians could separate and extract the hidden components of natural bodies. As the art of fire can penetrate beyond the surface of bodies, alchemy, for Paracelsus, leads to the knowledge of natural bodies. Indeed, Paracelsians used to style themselves philosophers by fire and some of them, like Petrus Severinus (c. 1540-1602) and Oswald Croll (c. 1560-1608), developed the cosmological and theoretical aspects contained in the works of Paracelsus, providing a set of theories that stood in opposition to the Aristotelian philosophy of nature.[7] Libavius explicitly criticized both the language and the claims of Paracelsus and his followers, and aimed at subordinating chemistry to natural philosophy, which, in his view, meant Aristotelianism. Whereas the Paracelsians wanted to overthrow the traditional medical curriculum and endeavoured to make chemistry the very foundation of medicine and philosophy, Libavius made it clear that the aim of chemistry was to be of assistance to medicine, not to create a new medicine, or, even worse, a new philosophy of nature. Libavius' program was twofold: he wanted to rescue chemistry from the hands of the Paracelsians and to establish principles, axioms for chemistry, after the model of demonstrative science. For Libavius, chemistry was not to be left to 'philosophically uninformed artisans', having but sporadic experience. The true chemists had to know the causes of natural phenomena and the reason of his practical procedure. (Moran 2007: 33-6). Establishing a difference between the 'true chemists' on one side and the vulgar chemists (i.e., illiterate pretenders) on the other was crucial to legitimate chemistry. This was a recurrent theme in much of the alchemical literature and is well illustrated by Michae Maier. In his *Examen fucorum* (1617) Maier stressed the opposition between the true adepts who search the secrets of nature and those he called false alchemists, namely, illiterate practitioners who failed to understand the divine nature of the Art and sought only vulgar gold, whom he compared to the useless drones of the hive.[8] Libavius aimed to construct the canon of alchemical texts to be part of the true chemists' education. The list included the pseudo-Aquinas, Albert the Great. Bernardus Trevisanus, Geber, Lull and Arnold of Villanova. No Hermetic tract features in the list. No claim of the ancient origins of chemistry is to be found in Libavius' works. He evidently ruled out the search for the ancient origins of chemistry – a practice adopted by a number of alchemical writers trying to legitimate the Art. In Libavius' view, alchemical texts lacked principles, method and order. The texts he recommended provided some knowledge of chemical operations, but, in order to make chemistry a legitimate form of art, it was necessary to organize its contents systematically, i.e., according to demonstrative order.

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[7] Severinus (1571) and Croll (1609).

[8] On Michael Maier, see B.T. MORAN, *The Alchemical World. of. the German Court. Occult Philosophy. and Chemical Medicine in the Circle of Moritz of Hessen (1572-1632),* Stuttgart, 1991, pp. 102-111.

Libavius' plan to elevate chemistry to the rank of a teaching discipline met the opposition of the Paris medical Faculty which rejected chemistry as stranger to medicine and reassessed the traditional medical curriculum. The University opposition delayed the introduction of chemistry teaching in the University of Paris, but did not prevent the teaching of private chemical courses in the city. German universities showed a more tolerant attitude towards chemistry, which entered the Universities of Marburg and Jena in the early decades of the 17th century. In the course of the seventeenth century, chemical teaching and chemical textbooks contributed to bring about a change of the role and the status of chemistry. While at the beginning of the century chemistry was regarded as practical art - its object being the separation of the pure from the impure- later in the century chemistry gained both intellectual and social respectability and became integrant part of natural philosophy.[9] As we gather from the definition of chemistry to be found in the French textbooks (notably those of Lefevre and Lemery) its aims were no longer confined to the separation of pure from impure substances. Chemistry dealt with the composition of mixed bodies and with the theory of matter.

In the first part of this paper we take into account the changing views of chemistry as contained in the chemical textbooks published in the 17th century. In the second part, we examine the relationship between chemistry and the mechanical philosophy, trying to assess the different ways in which chemistry and the mechanical philosophy interacted, in other words, whether all versions of mechanical philosophy were incompatible with the existence of chemistry as independent discipline.

Early chemical Courses in the German States

In 1609 the Landgrave Maurice of Hesse-Cassel (1592-1627) established a chair of *chymiatria* at the University of Marburg, which was occupied by Johannes Hartmann (1568-1631).[10] As we gather from Hartman's works, he did not adopt Libavius' views of chemistry. He held the Paracelsian theory of *tria prima* and deemed chemistry not as subordinated to natural philosophy (*physica*) but as an independent discipline. As he put ut, 'it has a splendour of its own'. Chemistry could discover the major *arcana* of nature (antipathies and sympathies) and, unlike *physica* (which is filled with endless disputes), produces useful and good things for life. Though Hartmann did not reject traditional medical learning, he did not see chemistry as ancillary to medicine, but as one of its foundations. He insisted that the preparation of remedies was not to be left to unskilled

9 Hannaway (1965), p. 52; Hannaway (1975); Moran (1991b), pp. 50-67.
10 Moran (1991a).

apothecaries, but to the chemical physicians, those who learn the art of fire and the way to extract active principles from natural bodies.(Hannaway 1965: 82)

At the University of Jena chemical teaching started in the mid-1630s. The public lectures were given by Zacharias Brendel Jr (1592-1638) and were based on a textbook entitled *Chymia in artis formam redacta* (1630). Brendel's views were less innovative than Hartmann's. He rejected the claims of the 'chemical philosophers' – who, in his view, subverted the traditional hierarchy of disciplines - and unambiguously restated the ancillary role of chemistry. For Brendel, chemistry was a practical art, ancillary to medicine and its end was to produce chemical remedies.[11] After Brendel chemistry was taught at Jena by Werner Rolfinck (1599-1673). Rolfinck was a student of Daniel Sennert at Wittenberg and was appointed professor of anatomy, surgery and botany at the University of Jena, where he also taught chemistry from 1637. His textbook, bearing the same title as Brendel's (*Chymia in artis formam redacta*), aimed at promoting chemistry as an academic discipline, following the traditional academic pattern of the *quaestiones disputatae*. Rolfinck promoted chemistry as an academic discipline in two ways: 1. He separated chemistry (metallurgy and pharmaceutical chemistry) from alchemy – which he ruled out as *art sine arte*. 2. He maintained that it is based on reason and experiment. He did not reject traditional medical learning and imposed severe restrictions to the role of chemistry, which he defined along the following lines: "Chemistry is the art of dissolving solid bodies, coagulating solutions, so that the pure is separated from the impure and safe medicaments are prepared." Like Sennert, he was critical of Paracelsianism and saw chemistry as a practical art, playing an ancillary role to medicine ("Domina est medicina, chemia serva"). He stated that "Chemistry does not merit to be included among the sciences, but among the arts; moreover, it is not a peculiar art, distinct from the pharmaceutical part of medicine, but is part of medicine."[12]

Chemistry in 17th Century Paris

If we move from the German states to Paris we find chemists fighting against the medical establishment to introduce chemical lectures. It was the support of the King's physicians and of members of the court that made it possible to chemical physicians to establish courses in the city, despite the attacks of the Paris medical faculty against chemistry and Paracelsianism. Conflicts were very harsh and no room was left to compromises like the one proposed by Libavius. The chemical physicians often followed Paracelsus' teachings and stressed the opposition between chemistry and traditional medicine. Their view of chemistry was not the one to be found in German

[11] Brendel (1630), pp. 9-10; Hannaway (1965), pp. 91-95.
[12] Rolfinck, (1661). Rolfinck was 'Director Exercitii Chymici'. Hannaway (1965), pp. 96-99; Partington, (1961-1970), 2, pp. 312-14.

textbooks like those of Brendel and Rolfinck. They rather emphasized the independent status of chemistry and its claims to investigate the principles of mixed bodies. Most French chemical textbooks adopted Paracelsian views, presenting chemistry as the foundation of a new medicine and of a philosophy of nature alternative to Aristotelianism.

We start with Jean Beguin's *Tyrocinium Chymicum,* which is commonly considered the first chemical textbook. Beguin's *Tyrocinium* was mainly practical in nature and had a minimum of theoretical contents, being principally aimed at teaching chemical operations to apothecaries, who were wanted chemical skills to undergo the examination required by the guild.[13] The *Tyrocinium Chymicum* was first published in 1610 as a slim anonymous volume of 70 pages, being collection of instructions, compiled by Beguin's students.[14] It has been remarked that the 1610 edition of the *Tyrocinium* was indebted to Libavius' *Alchemia* of 1597. It is apparent that the definition of chemistry therein contained is based on Libavius and stresses the practical nature of alchemy: 'Alchemy is the art that teaches to separate the pure from the impure, or the art of perfecting the magisteries, and of separating the pure essence from mixed bodies'.[15] With the exception of a passing reference to Paracelsus' spurious *De Tinctura Physicorum,* it does not contain any substantial challenge to the philosophical and medical tradition, and explicitly states that chemistry is ancillary to medicine. Though Beguin practiced alchemy, he carefully distinguished alchemy, i.e., the transmutation of metals, from practical chemistry - that was the only subject of his *Tyrocinium*: 'There are two species of alchemy; one of which, Pyrotechnia, or the art of resolution, purification and transmutation of metals by fire, I here pass over in silence. The other which extracts the most subtle spirits from metals, gems, and plants…'.[16]

The 1612 edition, the first bearing the author's name, is larger than the previous one and is considerably different in arrangement. It contains a view of chemistry which is similar to the one contained in the 1610 edition: 'Chemistry is the art of dissolving natural mixed bodies, and of recombining the same when dissolved and of reducing them into salubrious, safe, and grateful medicaments…' Beguin established the difference between chemistry and natural philosophy (*physica*) as follows: whereas physica is purely theoretical, chemistry is both theoretical and

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[13] Kremers and Urdang (1940), pp. 76-7.
[14] For a bibliographical study of the *Tyrocinium*, see Patterson (1937).
[15] Beguin described a magistery as follows: 'A Magistery is when the mixed body is so prepared by chymical artifice without extraction; as all its homogeneal parts are preserved, and deduced to a more noble degree, either of substance or quality, the external impurity being segregated.' Beguin (1612), p. 117.
[16]Beguin (1610), p. 3. Beguin's practice of alchemy is attested by his own letter to Jeremias Barth, a native of Silesia, who was his pupil in Paris. The letter is dated 6 March 1613. Beguin's letters are in the 1618 Latin edition of the *Tyrocinium*, published by Barth under the title *Secreta Spagyrica*. See Petterson (1937), p. 273.

practical. (Beguin 1612: 1-2). A comparison between the subsequent editions of the *Tyrocinium* clearly shows that the conflicts between the Paracelsians and the Medical Faculty affected the contents, notably the definition of the aims and status of chmistry. In the 1615 edition of the *Tyrocinium*, published with the title of *Les elemens de chymie,* Beguin, who was censured by the Medical Faculty, dropped the reference to Paracelsus and replaced the previous Preface with a new one, attesting his submission to the Medical Faculty. The members of the faculty - whom he had previously styled 'mysochymists' - are now called 'learned and illustrious physicians.' In the new Preface Beguin accepted the Medical Faculty's censures. He declared: '[I] had written the new edition under the censorship of the learned and illustrious members of the Medical Faculty of this town, to the judgment of whom I have always submitted and do submit myself, recognizing that this science [i.e. chemistry] to reach its best perfection, should be conducted according to the doctrine they profess.'[17] In 1618 two different editions of the *Tyrocinium* saw the light. One was published at Koenigsberg, with preface and notes by Johann Hartmann (under the pseudonym of Christopher Glückradt), the other appeared with the title of *Secreta spagyrica revelata* and was edited by Beguin's former student Jeremias Barth. Hartmann extolled the importance of chemistry for medicine and quoted Severinus' rejection of traditional medical learning.[18] Jeremias Barth inserted a praise of Paracelsus, of Du Chesne and of the new chemical remedies, while rejecting Galenical medicine.[19] By contrast, the posthumous French edition of 1620, which was prepared for the press by some Jean Lucas de Roy, was heavily affected by the University's attacks against Paracelsianism.[20] It is apparent that the pressures of the Paris Medical Faculty were ultimately responsible for the preface, where Paracelsus and his followers are explicitly criticised.[21] Beguin's *Tyrocinium* enjoyed enormous diffusion all over Europe and was instrumental in giving chemistry a larger audience, contributing to the standardisation of terminology and procedures.

The censures from the Paris Medical Faculty did not hinder the diffusion of chemical lectures in Paris. Thanks to the support given to chemical physicians by members of the court, chemistry gained momentum in Paris in the 1620s and in the early 1630s. Chemical lectures were held in different Hotèls particuliers of Paris. In 1633, with Richelieu's support, Théophraste Renaudot started his conferences promoting chemistry and a number of Paracelsian remedies among a large public. Renaudot maintained that chemistry was not subordinated to medicine, but

[17] Petterson (1937), p. 275.
[18] Beguin (1618a); Petterson (1937), pp. 281-282.
[19] Beguin (1618b); Petterson (1937), pp. 283-5.
[20] Petterson (1937), pp. 288-9.
[21] Petterson (1937), pp 275-6. The exact date of Beguin's death is unknown; we might conjecture that he died in 1619. Barth's edition of 1618 does not refer to Beguin's death, while in the 1620 edition of the *Tyrocinium* mentions Beguin's death. See Petterson (1937), p. 288.

was integrant part of it: “we say rather that the three parts of Medicine, or its three ancient sects, are the three parts of the World, Europe, Asia, and Africa; and Chymistry is that New World, lately discover’d, not less rare and admirable than the others, provided it be as carefully cultivated, and rescu’d out of the hands of Barbarians”. The Medical Faculty saw the conferences as a threat to the medical tradition and managed to put an end to Renaudot’s *Bureau d'Adresse* in 1642.[22]

Parisian iatrochemists achieved an important success in Paris with the foundation of the Jardin du Roi in 1640 , thanks to Guy de la Brosse. Guy de la Brosse, who was a student of Beguin’s and adhered to Paracelsianism, introduced chemistry among the disciplines to be taught in the Garden.[23] The Medical Faculty tried to prevent the opening of the botanical garden, but did not succeed. The Faculty then tried to obtain the right to appoint teachers, but failed. The Jardin du Roi housed a laboratory and in the late 1640s became the centre of chemical teaching in France. The courses were advertised in Latin but given in French. They were open to the public and were free. There was no enrolment of students and no certificates attesting the attendance at courses were granted, but the Jardin du Roi did not provide academic qualification. While the early chemical courses were mainly attended by apothecaries, those held in the Jardin du Roi had much larger audience, being attended by medical students (possibly against the wish of the faculty), physicians, natural philosophers and virtuosi.[24] William Davidson (or Davisson) of Aberdeen was the first teacher of chemistry at the Jardin du Roi. He settled in France about 1618 and in 1648, thanks to François Vautier, who was superintendent of the Jardin, he was appointed *intendant*. Before starting his teaching at the Jardin du Roi, Davisson had already taught privately in Paris and had published his chemical course (*Philosophia Pyrotechnica… seu Curriculus Chymiatricus* 1633-1635), containing a complex mixture of Neoplatonic, Paracelsian and corpuscular theories. The French edition (*Les Elemens de la philosophie de l’art du feu, ou chymie*, 1651), translated from Latin by Jean Hellot, *Maître Chirurgien*, is shorter than the original, the theoretical part was abbreviated (some philosophical and cosmological speculations were dropped), and the practical part was extended and rearranged. In it chemistry is described as both science and art, having ancient origins, going back to Hermes Trismegistus and to Moses. Davidson also tried to show that Paracelsian chemistry was not incompatible with Galenism. Davidson’s preoccupation to make chemistry a subject of instruction is attested by the way he rearranged the theoretical section, namely, in a demonstrative way, following the model of Euclid’s *Elements*. He recommended his book to students of philosophy, medicine, surgery and pharmacy. Davidson’s lectures at the Jardin du Roi were very successful and were attended, among others, by English residents in Paris, namely John Evelyn and

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[22] Solomon (1972), Debus (1991), pp. 84-95.
[23] Guerlac (1972); Howard (1978); Howard (1981).
[24] Contant (1952); Laissus (1986).

Thomas Hobbes.[25] In the 1650s Paracelsian views and remedies were supported by an increasing number of doctors, and half the doctors of the Faculty accepted the new chemical drugs.[26]

The changing role of chemistry in Paris, as well as the increasing support obtained by Paracelsianism (and then by Helmontianism), had a noticeable impact on chemical textbooks, in particular on those written by Nicaise Le Fèvre and Nicolas Lemery. In their textbooks chemistry was described as the key to the knowledge of nature. This view was first articulated by Nicaise Le Fèvre (c. 1610-1669), who in his *Traicté de la Chymie* (1660, 2nd ed. 1669), declared that 'la Chymie est la veritable clef de la nature.' (Le Fèvre 1669, pp. 3-4) For Le Fèvre, chemistry investigates the Principles, out of which natural bodies are compounded; it discloses the causes of their generations and corruptions, as well as of all the changes and alterations to which they are liable.[27] Le Fèvre originated from Sedan and settled in Paris, where he was instructed by Samuel Cottereau Duclos.[28] He taught chemistry privately from 1647 and then publicly at the Jardin du Roi from 1651. Among his students we find Sir Kenelm Digby, who favoured Le Fèvre's eventual appointment as chemist to Charles II. In 1660 Le Fèvre published his *Traicté de la Chymie* and in the same year he moved to London.[29]

Le Fèvre's emphasis on the double nature of chemistry (including theory and practice), was aimed at raising chemistry above its traditional status of practical discipline, and at the same time to show its superiority to Aristotelian philosophy, that in his view had no practical use. Like William Davidson, his predecessor at the Jardin du Roi, Le Fèvre emphasized the ancient and noble origins of chemistry, and maintained that chemistry was both science and art. He distinguished three different kinds of chemistry, following a precise hierarchical order. At the top level he put what he called philosophical chemistry. This is science and deals with the principles of natural bodies, as well as with the generation of animals, plants and minerals. Its object overlaps with that of natural philosophy (*physique*). The second is iatrochemistry, which depends on the philosophical chemistry and is a mixed science, both theoretical and practical. The third is pharmaceutical chemistry, which is subordinated to iatrochemistry and is purely practical, since it has practical ends only. As he put it, 'it belongs to the profession of the apothecary who is directed in his work by the precepts of iatrochymists'.[30] This hierarchy of disciplines shows that one of Le Fèvre's principal aim was to stress the superiority of iatrochemists over the apothecaries. While the early chemical textbooks were mainly practical in orientation, Le Fèvre's textbook gave increasing importance to theory,

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[25] Read (1961), pp. 77-78.
[26] Brockliss (1978), p. 244.
[27] Bourchemin (1969).
[28] Todériciu (1974).
[29] Metzger (1623), pp. 62-82; Partington (1961-70), vol. 3., pp. 17-24.
[30] Le Fèvre (1669), p. 7; see Mandosio (1998), pp. 43-48.

notably the discussion of the chemical principles and elements of natural things. The aim of chemistry, as far as its philosophical part is concerned, was to establish the number of principles and their properties. (Le Fèvre 1669, p.1) The other aim was the one Paracelsus and Severinus had insisted upon, namely, spiritualising bodies and corporifying spirits. Le Fèvre devoted a chapter of his textbook to the universal spirit (*L'Esprit universel*), which he defined as a simple and homogeneous substance, the source of life in the universe – a definition that he borrowed from Pierre Jean Fabre (c. 1588- c. 1658).[31] Following the Paracelsian chemical philosophy, notably of Petrus Severinus' *Idea Medicinae Philosophicae*, Fabre maintained in his *Abrégé des secrets chymiques* that chemistry was not just a practical art, but true science (*une vraye et solide science*) that teaches us out to extract the spirit of the world, the active principles contained in all natural bodies.[32]

Like Beguin and Le Fèvre, Nicolas Lemery (1645-1715) was a Protestant. He was the son of a *procureur* at the Parlement of Rouen, was apprenticed as an apothecary at Rouen, and then settled in Paris, where in 1666 he attended Christophle Glaser's classes at the Jardin du Roi – apparently with little profit. In 1668 he moved to Montpellier.[33] Back from Montpellier, Lemery settled in Paris in 1672, where he worked in a laboratory in the Hotel de Condé. He continued his training under the direction of Protestant apothecaries, notably Bernardin Martin, apothecary to the Prince de Condé, and Elie Seignette. His close association to Martin gave him access to the circle of savants who gathered around the Prince de Conde's confidant, Pierre Michon, the Abbé Bourdelot (1610-1684). Lemery had access to the conferences organised by Bourdelot, that took place from 1665 to 1684, and so he became acquainted with members of the Académie des Science, including Joseph Pitton de Tournefort (1656-1708) and Joseph-Guichard du Verney (1648-1730). Lemery also attended conferences organised by Henry Justel (1620-1693), which gave him the opportunity to make the kind of contacts that might serve to advance his career. [34] His lectures, that occupied 3 or 4 days a week for 8 weeks, were advertised in Nicolas de Blegny's *Temple d'Esculape* and were followed by a large number of students, including academic physicians and natural philosophers. Among them, we find Jacques Rohault, François Bernier, Adrien Auzout, Joseph Pitton de Tournefort, and two English students, namely, William Harris and John Keill – who were both authors of translations of Lemery's *Cours de Chymie* into English. In 1699 Lemery became a member of the Académie des Sciences, where he contributed with a number of papers on chemical,

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[31] Le Fèvre (1669), pp. 12-16.
[32] Fabre (1636), p. 10; Matton (1992-1996).
[33] Dulieu (1986), pp. 00-00
[34] On Lemery's life see Guédon (1974), pp. 212-228; Sturdy (1995), pp. 308-12; Powers (1998). For Bourdelot and Justel see Brown (1934), pp. 161-184; 231-253 and *passim*.

mineralogical and geological subjects. In order to promote chemistry among savants, Lemery set out to distance chemistry from alchemy and claimed that he got rid of the obscure terminology that made this discipline suspicious to contemporary natural philosophers:

> La pluspart des Autheurs qui ont parlé de la Chymie, en ont écrit avec tant d'obscurité, qu'ils semblent avoir fait leur possible pour n'estre pas entendus. Et l'on peut dire qu'ils ont trop bien réüssi, puisque cette Science a esté presque cachée pendant plusieurs siecles, & n'a esté connuë que de tres-peu de personnes. C'est en partie ce qui a empesché un plus grand progrés que l'on eust pû faire dans la Philosophie.[35]

Lemery's arguments against alchemy were by no means original; they were intended to legitimate chemistry among natural philosophers, by vindicating its role against persistent opposition and scepticism. Lemery also rejected the Paracelsians' spirit of the world as a metaphysical concept, having nothing to do with the investigation of nature. He considered spirit (that he identified with mercury) to be one of the active principles, being a light and penetrating substance.[36] The theory of five principles as contained in the first edition of his *Cours de Chymie* (1675) is rather traditional. He distinguished three active principles (spirit/mercury, oil, salt) and two passive ones (water and earth). His view changed around 1680. In the 1681 edition (4th edition) of his textbook, Lemery introduced a section entitled 'Remarques sur les Principes', which is likely to be an answer to Boyle's critical arguments against the spagyrical principles as contained in *Producibleness of Chemical Principles* (appended to the second edition of the *Sceptical Chymist*, 1680).[37] Lemery did not accept Boyle's view that the five principles were produced *ex novo*, and not extracted by fire. Yet, he subscribed to Boyle's argument against the traditional theory of chemical principles, namely, claiming that they cannot be obtained from **all bodies**. Lemery admitted that the principles could not be extracted, for instance, from gold and silver. In addition, he asserted that volatile salts obtained by distilling plants did not pre-exist in them, but were produced by fire. Lemery adopted a full-wedged corpuscular theory of matter and made use of mechanical models to explain a number of chemical reactions. Lemery claimed that he employed the term principle as a 'working tool', not

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35 Lemery (1675), 'Preface', sig. aiij[r]. In the the fourth edition (1681) of the *Cours* Lemery introduced a harsh criticism of alchemy, that remained in the subsequent ones, see Powers (1998), pp 169-170.

36 'Le premier Principe qu'on peut admettre pour la composition des Mixtes est un esprit universel, qui étant répandu par tout, produit diverses choses selon les diverses Matrices ou Pores de la Terre dans lesquels il se trouve embarassé: mais comme ce Principe est un peu Metaphysique, & qu'il ne tombe point sous les sens, il est bon d'en établir de sensibles', Lemery (1675), pp. 3-4. On the chemical notion of spirit, see Clericuzio (1994b)..

37 For a comparison of the different edition of Lemery's *Cours*, see Bougard (1999); for Boyle's criticism of the five-principle theory, see Boyle (1999-2000), vol. 2, pp. 205-378 (*Sceptical Chymist*) and vol. 9, pp. 19-120 (*Producibleness of Chymicall Principles*); see Clericuzio (1994a).

in a strict sense, since the principles could be further divided. As he put it in the 1683 edition, the chemical principles are principles for us, not in nature:

> Le nom de Principe en Chymie, ne doit pas estre pris dans une signification tout à fait exacte; car les substances qu'on appelle ainsi, ne sont Principes qu'à nostre égard, & qu'entant que nous ne pouvons point aller plus avant dans la division des corps, mais on comprend bien que ces Principes sont encore divisibles en une infinité de parties qui pourroient, à plus juste titre, estre appellées Principes. On n'entend donc par Principes de Chimie que des substances separées & divisées autant que nos foibles efforts en sont capables.[38]

Lemery's *Cours* was not confined to the teaching pharmaceutical chemistry. According to Lemery, chemistry

> nous enseigne comme le eaux vitrioliques & metalliques se coagulent dans les entrailles de la terre & font les mineraux, les metaux & les pierres, selon les diverses matrices qu'elles rencontrent. Elle nous donne une idée sensible de la vegetation & de l'accroissement des animaux par les fermentations & par les sublimations. Elle [sc. la chimie] nous apprend par la distillation comment le Soleil ayant rarefié les eaux de la mer, les éleve en nuës qui après distillent en pluyes ou en rosées: enfin par la separation du pur d'avec l'impur; elle nous fait comprendre l'ordre que Dieu a observe dans la creation de l'Univers.[39]

His chemical textbook included a variety of topics, mirroring the ambitions of French chemists. It dealt with the chemistry of plants (a subject which was thoroughly investigated by members of the Académie des Sciences), with metallurgy, and with agricultural chemistry, giving instructions on subjects like soil chemistry and fertility, plant nutrition, and the application of fertilizers. In the fifth edition (1683) of his *Cours* Lemery included a lengthy discussion of phosphorus containing material taken from Boyle's *Aerial Noctiluca* (1680).[40]

Chemistry and Mechanical Philosophy

Lemery's views of principles bring us to consider the relationship of chemistry to the mechanical philosophy. According to Marie Boas, Chemistry became integrant part of science when it was based on the mechanical philosophy. This, according to Boas, was Boyle's major achievement. As she put it: "[Boyle's] chemistry was sufficiently theoretical, but also … rational and mechanistic to be regarded as worthy of inclusion in the new experimental natural philosophy."[41] A different view was held by William Newman, who tried to demonstrate that Western alchemy was mechanical

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[38] Lemery (1683), pp. 5-6.
[39] Lemery (1675), 'Preface', sig. aiij^{v}.
[40] Lemery (1683), pp. 549-569. On phosphorus see Golinski (1989).
[41] Boas, (1958): 67.

from its very beginning and there is no point to speak about conflicts between mechanism and chemistry, because, following, the ps-Geber, alchemists explained chemical phenomena in terms of addition, recess or transposition of insensible corpuscles.[42] I have dealt with Newman's views elsewhere and here I want only to stress that his view is based on a highly selective reading of alchemical sources. In a perceptive article published in the Proceedings of the Philadelphia Conference on Alchemy and Chemistry (2007), Luc Peterschmitt argued that chemistry was incompatible with mechanism, in other words, he stated, the mechanical philosophy denied the very possibility of chemistry as independent discipline.[43] As far as Peterschmitt's argument is concerned, I think that there is no doubt that Cartesian mechanism left no room to chemistry as independent discipline, but this was not the case with other versions of the mechanical philosophy. This is not the place to embark on a definition of 17th century mechanical philosophy, but some considerations on the mechanical philosophy are to be included in this paper. If we say that theories explaining natural phenomena by means of matter and motion were mechanical, then we have to admit the existence of a variety of mechanisms in the 17th century. I am prepared to accept this view, provided that we distinguish different kinds of mechanical philosophy. I want to take into account two topics that established the main differences within what historians commonly called mechanical philosophy. First: the origin of motion and the way it is transmitted. On this topic the difference between Descartes and Gassendi is huge. For Descartes, matter was inert and motion was transmitted by impact only. For Gassendi, matter had an internal principle of movement. Second: reductionism. Not all mechanists pursued the reduction of all phenomena to the primary affections of corpuscles, namely, size and shape (and motion). Some mechanical philosophers admitted the possibility of so-called intermediate theories, i.e., theories based on the sensible properties of corpuscles, not on the primary affections of particles of matter. This second point is particularly relevant to our investigations of the relationships of mechanism to chemistry. One more point to be stressed here is that not all corpuscular theories of matter were mechanical. This is well attested by a number of corpuscular philosophers, including Sennert, Basson, Davidson, De Clave, Willis and Cudworth, who resorted to substantial forms, spirit, plastic nature as immaterial (or semi-material) agent acting on matter.

Let's go back to our main point, i.e., chemistry and mechanical philosophy. If we consider the Cartesians, we see different attitudes towards chemistry. As Peterschmitt pointed out, Cordemoy and Rohault denied chemistry the status of independent discipline, since only mechanical theories provided true explanations of natural phenomena. For Rohault, chemists only perform experiments,

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[42] Newman (2006), passim.

[43] Peterschmitt (2007), p. 201.

but, in order to explain them, one should resort to mechanical theories. Nicolas Hartsoeker (1656-1725) and Pierre Sylvain Régis were slightly more liberal towards chemistry. In *Conjectures Physiques* (1706) Hartsoeker pursued a reductionist program in chemistry, stating that the different chemical substances and their properties were the outcome of their geometrical forms, their sizes and weights. Acid salts are made of long and sharp particles, which, when mixed with water, form acid spirits. The latter are described as balls studded with sharp points. Hence they can easily penetrate the texture of bodies. Alkali have hollow cylindrical particles, where acids' points can enter.[44] Régis did not rule out the chemical principles and saw chemistry as a proper science. He did not deny the possibility of explaining chemical principles in terms of mechanisms, but he saw this task out of reach. As we have seen, Lemery combined mechanism and chemistry and produced one of the most influential chemical textbooks.

We now turn to Robert Boyle. A number of historians have followed Fontenelle's views that Robert Boyle was a physicists and gave little or no contribution to chemistry. As Victor Boantza pointed out, Fontenelle's distinction between Boyle's physics and Duclos' chemistry is misleading if taken at face value. (Boantza, 2007: 192). Fontenelle's opposition was echoed in the article 'Chymie' for the *Encyclopédie*, written by the Stahlian chemist Gabriel François Venel. Venel saw Boyle as the scientist who promoted mechanical philosophy rather than chemistry. Venel established clear boundaries between chemistry and physics, and complained that Boyle "est trop exactement physicien corpusculaire-méchanicien, ou physicien proprement dit", and suggested placing him among the physicists, rather than among the chemists.[45] This view of Boyle was restated by Kuhn in 1952. Kuhn stressed the prevailing mechanical approach to chemistry in Boyle's work as follows: "Boyle's faith in the corpuscular principles of the mechanical philosophy is the cause of his emphasis in chemistry upon structure, configuration and motion, as well as a cause of his rejection of explanations in terms of inherent characteristics of the ultimate corpuscles". Boyle's chemistry, according to Kuhn, was based on mechanical philosophy, and for this reason it was "incompatible with the belief in the existence of enduring elements".[46]

It is my contention that Boyle did not consider chemistry as a branch of physics, since he did not reduce all chemical phenomena to the geometrico-mechanical affections of the particles of inert matter. Boyle questioned the spagyrical principles, but did not rule out the existence of simple and homogeneous chemical substances. He denied this title to those bodies (three or five) which

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44 Hartsoeker, *Conjectures Physiques* (Amsterdam, 1706), pp. 101-130.

45 *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers, par une société des gens de lettres*, 17 vols. (Paris, 1751-1765), iii, p. 435. On Venel see E.M. Melhado, 'Chemistry, Physics, and the Chemical Revolution', *Isis* 76 (1985), 195-211 (esp. pp. 196- 9). A view similar to Venel's is to be found in the *Histoire de l'Académie des Sciences*, 11 vols. (Paris, 1729-34), i, p. 79.

46 T.S. Kuhn, 'Robert Boyle and Structural Chemistry', *Isis* 43 (1952), 12-36.

chemists commonly believed to be the ingredients **of all mixed bodies**, but he did rule out that simple chemical substances could be found by using more sophisticated methods of analysis than the standard fire analysis employed by chemists. Boyle thoroughly investigated the possibility that Mercury was a simple and homogeneous substance. His rejection of the current classification of chemical substances did not imply that he ruled out the possibility of chemical classification and proposed different criteria to classify substance – as attested by his position on the Acid/alkali theory. His aim was to increase the number of what he called “chemical families”, as, in his view, chemists had based their classifications on a few similarities which various substances showed, ignoring the differences which could be made manifest only if one forced them to appear by devising appropriate experiments.

In order to assess the status of chemistry in Boyle’s work and its relationship to mechanical philosophy, we have to consider the role of mechanical theories in Boyle’s explanation of natural phenomena. It is well known that Boyle considered that explanations based on the shape, size and motion of corpuscles were the primary, simplest and most comprehensive a naturalist could adopt.[47] However, he did not deduce all phenomena from the primary affections of corpuscles (shape, size and motion). As he put it, “there are so many subordinate causes between particular effects and the most general causes of things, that there is left a large field, wherein to exercise men’s industry and reason.”[48] This statement is not isolated. There are analogous statements both in Boyle’s published works and in his manuscripts. His adoption of what he called “intermediate theories” marked a significant departure from the strict mechanical philosophy and with the reductionism like Descartes’. Boyle did not believe that explanations based on the shape, size and motion of the primary corpuscles were the only valid ones. Indeed, he seldom referred to the “catholick affections of matter” when he dealt with chemical phenomena. Boyle had recourse to compound corpuscles, namely corpuscles endowed with chemical, not only mechanical, properties. Boyle’s interpretation of chemical phenomena was ultimately based on his classification of corpuscles.

In *The Origine of Formes* we find Boyle’s most systematic exposition of his matter theory. He started with the simplest particle, which, as he put it, “though it be mentally, and by divine Omnipotence divisible, yet by reason of its smallness and solidity nature doth scarce actually divide it”. Boyle calls these elementary particles *minima* or *prima naturalia*.[49] *Minima naturalia* here means corpuscles endowed with purely mechanical properties, namely shape, size and motion. It is remarkable that, unlike Descartes and Gassendi, Boyle does not formulate any hypothesis about the

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[47] Boyle, *Of the Excellency and Grounds of the Mechanical Hypothesis*, published as Appendix to *The Excellency of Theology* (London, 1674), *Works*, iv, pp. 70-1.
[48] Boyle, *The Usefulnesse*, *Works*, ii, p. 45.
[49] *The Origine of Formes*, *Works*, iii, p. 29.

shape and size of the primitive corpuscles. *Minima naturalia*, by their close union, form the primitive concretions or clusters of particles which we can call 'corpuscles of the second order'. According to Boyle, the corpuscles of the second order, which, being too small, are not perceived by our sense organs, are very rarely broken, but remain unchanged in the natural bodies they compose. These corpuscles form clusters of a higher order. Though here Boyle is not explicit about the properties of these corpuscles, we can assume that, unlike the *minima* or *prima naturalia* (i.e., corpuscles of the first order), the corpuscles of the second order (and of higher orders) have not just mechanical properties, but also chemical ones. This is what Boyle seems to imply:

> As, not to repeat what we lately mentioned of the undestroyed purging corpuscles of milk, we see that even grosser and more compounded corpuscles may have such a permanent texture: for quicksilver, for instance, may be turned into a red powder for a fusible and malleable body, or a fugitive smoke, and disguised I know not how many other ways, and yet remain true and recoverable mercury.[50]

This point is better illustrated by a passage of Boyle's manuscript on occult qualities:

> ... such clusters of Corpuscles as are so small as to be below ye Perception of ye Eye yet soe great as may conteyne both sensible qualityes at Last, and specifick propertyes... That likewise such small clusters of Particles as fall not under the sense may reteyne ye whole nature of a Mettall, may be easily evinc'd by diverse Chymicall Experiments...[51]

Boyle's classification of corpuscles according to their different degree of complexity is well elucidated by two fragments of a manuscript. The first reads as follows:

> I think it may be convenient to distinguish the Principles or more primitive, or simple Ingredients of mixt Bodys into three sorts, first Primary Concretions or Coalitions, next, Secondary mixts, and thirdly, decompounded mixts, under which name I comprehend all sorts of mixt Bodys, that are of a more compounded Nature, than the Primary, or Secondary ones newly mentioned…[52]

In the other fragment Boyle made a distinction between primary and secondary ingredients of mixed bodies:

> R/r in ye papers about Chymical Principles to make out the distinction betwixt

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[50] *The Origine of Formes, Works,* iii, p. 30

[51] BP, xxii, fol. 120^{r}, published in M. Boas Hall, 'Boyle's Method of Work: Promoting his Corpuscular Philosophy', *Notes and Records of the Royal Society of London* 41 (1987) pp. 111-143. According to M. Boas Hall, these notes were written before the publication of *The Origine of Formes and Qualities.*

[52] BP, iv, fol. 41^{r}.

> Corpuscles and Ingredients primordial or primary, and secundary … & the illustration of the former by Quicksilver, and of the latter by compounded sublimates, Cinabar…[53]

It is not accidental that both of these texts address the problem of the chemical mixture. The aim of Boyle's classification is in fact to make corpuscular philosophy viable to the explanation of chemical reactions.

To conclude, Boyle's adherence to the corpuscular philosophy, or, broadly speaking to the mechanical philosophy, did not imply that he left no room to chemistry as independent discipline. He often repeated that mechanical affections of matter were the more 'catholick' and more primitive ones. However, in Boyle's investigations of chemical phenomena chemical corpuscles played a central part and explanations based on the chemical properties of bodies were widely employed in his works. We have to stress here that Boyle's mechanism was by no means the same as the Cartesian one. Boyle's experimental work and his chemical theory unambiguously testify that he did not pursue the reductionist program of the Cartesians. He maintained (in *Usefulnesse of Experimental Philosophy*) that chemistry provided 'the key to nature' and often adopted chemical explanations of natural phenomena (notably those related to living bodies). This shows that Boyle, the mechanical philosopher, did not refuse chemistry its specific role in the investigation of nature - though he pursued a substantial reform of the methods and the terminology of chemistry.

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[53] BP, xvii, fol. 154^{v}.