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THEORY OR PRACTICE? THE EIGHTEENTH-CENTURY DEBATE ON THE SCIENTIFIC STATUS OF CHEMISTRY

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To say that chemistry has to approach its subject matter, the material structure of the world and the causes of material transformations, in a theoretical and practical manner, *experientia et ratione*, is a commonplace observation which can also be said of other fields.[1] Nevertheless, there seems to be a closer relationship between theory and practice in chemistry in the sense of an interdependence between both fields. Already in the seventeenth century, chemists agreed upon this as an almost self-evident maxim. If, however, in academic arguments either the one or the other aspect dominated, and at one point theory, and at another point practice, was considered to be the real master of the subject, then this was ultimately due to the after-effects of mediaeval scholastic schemes of scientific classification and their influence on the conception of science, combined with a usually and all too superficial distinction between θεωρία and πρᾶξις.[2]

Jean Beguin's well-known *Tyrocinium Chymicum* of 1608 is a good example of the long line of authors who first of all sought to define the character and particular nature of alchemy and then thoroughly, and for better reasons, of modern chemistry in the altercation of both theory and practice:[3]

> Cum autem omnes disciplinae vulgo sint vel theoricae vel practicae, Chymia non acquiescens in cognitione et contemplatione corporum mystorum ut scientia Physica; sed finem habens τὸ ἔργον πρᾶγμα . . . etiamsi forte inveniantur, qui theoria sola contenti ad jucundissimas artis hujus ἐγχειρήσεις . . . per accidens se non accingant.[4]

Two generations later Robert Boyle methodically discussed the permanent and immediate lack of theory concerning the practice of chemistry and developed one of the first empirical conceptions of theory. By putting experiment as the checking device for theories right into the centre of his chemical research programme,[5] he thereby finally banished the scholastic formal-speculative concept of theory from the sphere of scientific theory formation. Early historical surveys of chemistry, as long as they were not merely out to antedate as far as possible the beginnings of the subject at any price, also looked upon the connection of theory and practice as the origin of chemistry as a science.[6] Short, popular and easily remembered formulae such as *scientia practica*, *philosophia per ignem* or simply *pyrosophia* characterized this specific nature of chemistry.

Under the impression of the scientific revolution, reflection on the aim and method of chemistry was revived at the beginning of the eighteenth century,[7] but it did not however surpass the conclusions which had already been reached on the question of the relationship between theory and practice. If Mikhail Lomonosov in 1741 put forward in his *Elementa Chimiae Mathematicae* as the primary theorem the postulate that the real chemist must be both a theorist and a practitioner,[8] and if Pierre Joseph Macquer later eloquently pointed

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out the close connection between *raisonnement* and *experiénce*,[9] then both convictions may well have already belonged to a firm rhetorical store and become common knowledge to the extent that a more detailed discussion on the relationship between the two fields did not appear to be urgent as far as chemistry was concerned. This basic attitude was to change and give way to a new, violent controversy[10] only in connection with Kant[11] and as a result of the consciously felt chemical revolution, which gave rise to the heightened awareness of theory shown by the generation of chemists following Lavoisier. However, we shall not consider this later development in the present study.

The conventional division of theoretical and practical chemistry was therefore adhered to from stubborn habit, with few questions being raised concerning the inseparable connection between the two spheres. For example, Macquer's famous *Elemens de Chymie Théorique*, which appeared in 1749, was shortly followed by his *Elemens de Chymie Practique*, where it seemed as though it was a case of two themes which had to be individually treated.[12] Nevertheless, the extent to which the old contrast between theory and practice had already been blotted out is indicated by the very fact that Macquer largely defined his theoretical chemistry on the basis of its operations—"séparer . . . examiner . . . décomposer . . . composer . . . combiner . . . réunir . . . rejoindre"[13]—and that he closed each volume with a chapter on "Théorie de la construction des vaisseaux" and on "Théorie de la construction des fourneaux", which we would clearly assign to the practical side of the subject.

Writers of chemical textbooks unfortunately only very rarely gave accounts of the criteria of such subdivisions. Whenever they did so, however, didactic arguments for the keeping up of the traditional division seem to have been to the fore. As Macquer argued,[14] only theoretical chemistry allowed a logical, systematic representation from basic to complex, from known to unknown; practical chemistry, on the other hand, opposed systematic exposition, because here the subject matter (*e.g.* the procedure of analysis) dictated the form of representation. For the same reason other contemporary authors declared themselves in favour of a division into didactic and practical chemistry (*chemia dogmatica—chemia practica, experimentalis*) instead of the conventional terms.[15]

This, however, only solved the problem of the theory and practice in discussion within the discipline. In wider contexts the question whether chemistry works mainly theoretically or mainly practically kept turning up again wherever this division interferred with another ancient-mediaeval divisional system; namely wherever it came to represent chemistry as true science, *scientia*, or as mere art, *ars*. As late as the seventeenth century no less a person than Daniel Sennert, a first-rate chemical authority himself, denied the subject the quality of a *scientia* by reserving searches for ultimate causes exlusively to *Physica* and by allowing only productive *ποίησις*—principally with a pharmaceutical objective—to chemistry.[16] This idea also remained unchanged to a great extent in the public opinion of the eighteenth century. In 1786 even Immanuel Kant himself categorically denied the possibility of chemistry becoming mathematical and deductive, and decided that it could therefore "nichts mehr als systematisch Kunst oder Experimentallehre, niemals aber eigentliche Wissenschaft werden"[17] (be no more than a skilled art or experimental science, never a real science).

The chemists of the eighteenth century never tired of fighting this verdict and trying to prove that their subject was a real *scientia*. They even produced their own literary form of chemical programmes, which had the sole function of promoting chemistry and representing it as a science in its own right.[18] There is scarcely a definition of the subject from the pen of

an eighteenth-century chemist which did not push the rational and scientific aspect to the fore. But this made it necessary at the same time to assign a specific character to the newly understood science of chemistry in such a way as to delimit it from *physica*, the most general science, as well as from natural history and pharmaceutical practice.[19] As regards content, genuinely chemical levels of explanation, like the phlogiston theory, or specific research programmes involving the concept of elements, the theory of combustion, or the concept of affinity, could be provided, which allowed a plain and consistent definition of chemical knowledge and laboratory procedures.

The argument about theory and practice, revived again in the context of the *scientia-ars* debate, can however not only be seen in the internal development of chemistry. A more important reason is to be looked for in the sociological field and can only be understood from the particular way in which chemistry became institutionalized as an academic discipline.

Let us try to put ourselves in the position of the young subject of chemistry at the beginning of the eighteenth century, of a subject particularly in which the standard quotation of grey theory and the green trees of life—which, notably, comes from the mouth of Mephisto—swings to the other extreme. For it was precisely the experimenting chemist who had to brush off soot and dust from his coat before he entered the honourable meeting of his learned faculty colleagues. Herman Boerhaave's inaugural lecture as professor of chemistry in Leiden in 1718 clearly shows in its opening sentences the wall of disapproving reserve which the representative of an apparently very unacademic, ungainly, technical and even dirty business, such as chemistry, had to face:

> Hanc videtis sortem meam hodie, qui coram Principibus in Republica Viris, in consessu sapientissimorum Professorum, in conspectu denique hominum in omni scientiarum genere perfectissimorum, verba habere cogar de Chemia! de Chemia! quae aspera, horrida, laboriosa, a commercio Sapientum remota, ignota Eruditis vel suspecta, ignem, fumos, cineres, sordes spirans, vix ulla amoenitatis specie commendata habetur.[20]

Thirteen years later Boerhaave's successor, Hieronymus David Gaubius, repeated the same complaint from the same lecturn using almost the same words: Instead of well-stacked bookshelves the chemist only possessed his *apparatus*, and in the middle of ovens, vessels and pokers he was seen "non otiose ad pulpitam desidentem, sed atras carbone manus."[21] The origin of chemistry from the practice of metallurgists already gave away its low status:

> ab illiterato hoc rudique hominum genere primum exercita, depurata dein et obscurata ab impostoribus, in se horrida, laboribus plena, plena periculis, ab otiosis speculationibus aliena.[22]

That is why the learned men's repugnance at the "facies monstrosa" of chemistry was only too comprehensible.[23]

The unfortunate association with alchemy meant a further burden. After all, it had been precisely the falling apart of theory and practice, the discrepancy between highest theoretical demand and a most disillusioning reality, which had discredited alchemy: it promised the philosopher's stone and rushed its disciples into disaster; it promised life's elixir for which the alchemist worked himself to death. It is only too understandable that

chemistry did everything to demarcate itself from its predecessor and that it did not want to have anything in common with alchemy but the name:

> La Chymie . . . n'a heureusement rien de commun que le nom avec cette ancienne Chymie, et cette conformité est même encore un mal pour elle, par la raison que c'en est un pour une fille pleine d'esprit et de raison, mais fort peu connue, de porter le nom d'une mère fameuse par ses inepties et ses extravagances.[24]

With regard to public opinion, however, the image of the chemist still almost coincided with that of the alchemist. Textbooks and programme speeches of chemistry are full of complaints about this distorted image. Gabiel François Venel aptly characterized the situation in the Encyclopédie:

> Les personnes les moins instruites ne distinguent pas le chimiste du souffleur; l'un et l'autre de ces noms est également mal-sonnant pour les oreilles. Ce préjugé a plus nui au progrès, du moins à la propagation de l'art, que des imputations plus graves prises dan le fond même de la chose, parce qu'on a plus craint le ridicule que l'erreur.[25]

It was of little help when Venel merely dissociated himself from the gushing speculations of the alchemists and referred to the much tighter and completely different relationship of theory and practice in chemistry in order to delimit it also from those occult and speculative schools of thought which liked to see themselves as "higher chemistry" in the eighteenth century.

> Quelques demi-philosophes seront peut-être tentés de croire que nous nous sommes élevés aux généralites les plus hautes; mais nous savons bien au contraire, que nous nous en sommes tenus aux notions qui découlent le plus immediatement des faits et des conoissances particuliers, et qui peuvent éclairer de plus près la pratique.[26]

In the concurring judgement of the time, the two factors which were held most responsible for the delay in recognition of chemistry as an academic discipline and true science were that the stigma of the mere technical clung to the subject and that it came frightfully close to the shady practice and theoretical deception of a deceitful alchemy. In a textbook where the main aim was to educate a real *chemicus theoretico-practicus* instead of a blind *empiricus*, Johann Christian Zimmermann gave the following reasons for the low regard of chemistry:

> daß 1. die wenigsten Personen wissen, was eigentlich die Chemie sey, und das Wort Chemie insgemein . . . vor Alchymie nehmen, und dieserhalb mehrentheils einen Chymicum einen Alchymisten, Gold-Koch oder Betrüger zu nennen pflegen, . . . und daß 2. die Haupstücken der Chemie, ohne eine gehörige gesunde Theorie oder ohne die physicalischen Ursachen zu wissen oder einzusehen, nach empirischer Art, mehrentheils nur einzeln tractirt werden und, durch die Gewohnheir, gröstentheils zu kunst- und handwercksmäßigen Professionen geworden sind und auch also bearbeitet werden.[27]

Wherever theory and practice were mainly understood as a separation between intellectual disposition and manual activity in order to differentiate between *ars* and *scientia*, it no longer meant a mere quarrel of methods within the discipline for chemistry (which had anyway already decided this question for itself in principle), but rather social acknowledge-

ment and rank order in the system of sciences. Johann Georg Menn, first appointed professor of chemistry at Cologne in 1777, may therefore have had good reason for fearing that it might:

> zu geringschätzig erscheinen, daß ich mich hier bey gemeinen Verrichtungen, die man nur der mittleren Klasse der Menschen zu überlassen gewohnet ist, etwas umständlich aufgehalten und diese zur Empfehlung der Chemie angebracht habe.[28]

Since questions of the system of sciences and their hierarchy were of great importance at universities and in learned societies, if only because of their institutional structure, the connection of chemistry with the workshop or even the activity of an apothecary, was to its particular disadvantage in the academic world, as long as this could cause a conflict of interests between professional ethics and aspects of career for the individual chemist. Thus, in an obituary of Macquer it is indicated how far remote an academic attitude and a professor's dignity still was from practical work in a laboratory:

> Lorsque les progrès des conoissances les [professeurs] ont forcés a sortir des écoles pour interroger la nature dans les laboratoires, ils ont cru qu'il étoit de leur dignité d'y paroître avec leurs robes: ils sesonts réduits, par cet appareil, a l'impossibilité d'y faire autre chose que discourir.[29]

It is therefore not surprising that the professor of chemistry at the Jardin du Roi in Paris, although usually treated as equal to the other professors, had to be content with the title of a démonstrateur.[30]

Enlightened contemporaries were quite conscious of the social implication of the division into theory and practice. In his *Discours Préliminaire* of the *Encyclopédie*, D'Alembert harshly judged this social class-judging division into free and mechanical arts and branded it as an instrument of power of the physically inferior, intellectual ruling classes.[31] Denis Diderot judged similarly on the separation of the *arts libéraux* from the *arts méchaniques*.

> Cette distinction, quoique bien fondée, a produit un mauvais effet, en avilissant des gens très-estimables et très-utiles, et en fortifiant en nous je ne sais quelle paresse naturelle, qui ne nous portoit déjà que trop à croire, que donner une application constante et suivie à des expériences et à des objets particuliers, sensibles et matériels, c'étoit déroger à la dignité de l'esprit humain; et que de pratiquer, ou même d'étudier les arts méchaniques, c'étoit s'abbasisser à des choses dont la recherche est laborieuse, la méditation ignoble, l'exposition difficile, le commerce deshonorant, le nombre inépuisable, et la valeur minutielle.[32]

The baffling, almost literal, coincidence of these arguments with those of the debate about the status and rank of chemistry shows that the emancipation of the subject was also part of the great historical process in which the new bourgeoisie replaced the old contemplative ideal of life by a new one, which contained the ideas of progress and active formation of the world. In 1802 Humphry Davy put the chemist's new way of seeing himself at the beginning of his chemistry lectures at the Royal Institution:

> Science has given to him an acquaintance with the different relations of the parts of the external world; and more than that, it has bestowed upon him powers which may be almost called creative; which have enabled him to modify and change the beings

> surrounding him, and by his experiments to interrogate nature with power, not simply as a scholar, passive and seeking only to understand her operations, but rather as a master, active with his own instruments.[33]

In this context, it is most remarkable how, since the middle of the eighteenth century, chemistry had carried through the tendency to give up the sterile and restrictive distinction between theory and practice and replace it with the modern, still common, division of the subject into pure and applied chemistry, *chemia pura* and *chemia applicata*. What at first sight only seems to be a minor shift of trend, or even a mere battle of words, attentive contemporaries soon recognized as a carefully constructed re-conception of chemistry as a whole. After all, it meant the abolition of the fruitless division into theoretical science and practical arts. From then on, the kind of work, be it manual or intellectual, was no longer to decide the rank of the subject, but its real rank and dignity was to derive solely from its research aims.

In pure chemistry this points at principles and laws of material phenomena and transformations; in applied chemistry it points at their utilization for men's needs. The most intimate connection of chemical theory and experimental practice was, however, imposed on both areas as a self-evident condition.

The origin and descent of this conception can be determined very precisely. On 10 August 1751 the great Swedish chemist Johann Gottschalk Wallerius, a representative of the best mineralogical-chemical and agricultural-chemical school of thought in Scandinavia, wrote the "Bref om Chemiens rätta Beskaffenhet, Nytta och Wärde" to an anonymous addressee, who had it printed in the same year.[34] Here we meet explicitly the new distinction for the first time:

> Um eine gründliche Käntnis von der Chemie zu erlangen, halt ich es vor das bequemste, dieselbe in die abgesonderte (*chemia pura*) und die ausübende (*chemia applicata*) einzuteilen. . . . Die abgesonderte Chemie ist eine Wissenschaft von der Vermischung und dem Grundstoffe (*principiis*) [*sic*] der Körper. Die ausübende Chemie ist eine Kunst, welche zeiget, wie man durch Vermischung oder Teilung der Körper verschiedene, bei vielerlei Zufällen im gemeinen Leven nüzliche Stoffe zubereiten könne.[35]

The model for the naming was avowedly mathematics, which had already been familiar with the division into pure and applied mathematics for some time.[36] In the very same year, 1751, Wallerius programmatically introduced the new conception in minute detail in his dissertation *De nexu chemiae cum utilitate reipublicae*.[37] Through his textbook on physical chemistry, first written in Swedish, and in Latin and German translations, it decisively influenced the Scandinavian and German tradition.[38] Wallerius modified his original ideas in the textbook insofar as he now recognized that, with the help of his new distinction, not only the old division into theory and practice became untenable, but also the tiresome quarrel about *ars* and *scientia* had come to an end, as applied chemistry could now see itself as a "practising science" in all its parts.

> Denn die Theile der angewendeten Chemie bekommen das Ansehen der Wissenschaften oder der ausübenden Wissenschaften, indem sie nach Gründen errichtet werden, welche die reine Chemie hergiebt.[40]

On this basis Wallerius created his later, often adopted, sub-division of applied chemistry into nine single branches, namely medical chemistry, stone chemistry (*Lithurgica*), salt chemistry (*Halurgica*), fire chemistry (*Tejurgica*), metal chemistry (*Metallurgica*), glass chemistry (*Hyalurgica*), economic chemistry, colour chemistry (*Chromatica*) and arts or crafts chemistry (*Chemia technica seu opificiaria*).[41] According to Wallerius, each of these areas of application should be established on the principles of pure chemistry as the common "fundamentum, norma atque manuductrix",[42] and each of them was to represent an independent, self-contained science, comprising both theoretical and practical aspects.

In addition, thanks to the successful publications of the indefatigable Christian Ehrenfried Weigel, the man who, as professor of chemistry in Sweden's Greifswald, played the unique part of a mediator between Scandinavian and German chemists, Wallerius's conception rapidly made its way into German textbooks.[43] This was the case in particular, when the new generation of textbooks beginning with Erxleben's *Anfangsgründe der Chemie*[44] in 1775, superceded the older recipe collections or works which were subdivided by chemical operations. The new division into pure and applied chemistry soon entered general systems of learning.[45]

Admittedly few authors made such a clear distinction in their terminology as Wallerius or Weigel did. The latter had specifically pointed out that one should "angewandte oder besondere Chemie . . . mit der ausübenden oder practischen nicht verwechseln".[46] But from then on it was the idea of pure and applied science in Wallerius's sense that formed the basis of the terminological distinction, and not the other way round, when pure, physical or theoretical chemistry was still almost used synonymously and contrasted with applied, practical or experimental chemistry. The change of meaning was to be such a complete one that since the early nineteenth century the term "practical chemistry" has almost entirely disappeared from the technical terminology of most languages.

The rapid victory leads one to assume that the idea had, so to speak, been in the air for a long time. We also find it, almost simultaneously with Wallerius's *Bref* of 1751, in Lomonosov's unfinished outline of a teaching course of physical chemistry,[47] and, implicitly, in Venel's exposition on chemistry in the *Encyclopédie*.[48] In fact, the distinction between pure and applied chemistry fitted effortlessly into the conception of science of the Enlightenment, which had put to the fore the aspect of *utilité*, the common usefulness.[49] By establishing the subject on the formula "pure and applied chemistry" Wallerius tightly joined the way the discipline saw itself to the great and forward-looking trends of his time, the philosophical rationalism and scientism of the Enlightenment as well as to the programme of general usefulness which was to culminate in utilitarianism.[50] The utilitarian argument formed the image of chemistry in the eighteenth century to such an extent that since Boerhaave's *Elementa Chemiae*[51] of 1732, always quoted as a shining example of this, scarcely one textbook of chemistry and hardly one chemical periodical came from the press without recommending itself to the reader with the argument of the subject's usefulness. Even eighteenth-century definitions of chemistry regularly included this aspect in the characterization of their subject.

It is also noticeable how strongly, particularly in the linking of chemistry to general usefulness, the subject's connections with cameralistics [Kameralwissenschaft] and economics gained acceptance. This aspect of the history of chemistry has been quite wrongfully neglected. Johann Joachim Becher, the intellectual ancestor of phlogiston theory in the seventeenth century, had already been both a chemist and a political economist. Georg

Ernst Stahl, the great theorist of chemistry, had simultaneously prepared the way to application with important standard works of metallurgy and technology of fermentation (*Zymotechnia*). In this tradition the followers of Stahl increasingly incorporated chemistry together with the agricultural reform movement, and with technology (in Beckmann's sense) into the economic programme of the modern state. In relation to the increase and improvement of the country's products and to the tapping of new sources of raw material, chemistry promised economically important contributions to the increase of productivity and the raising of public funds.[53] The mining industry in German and Scandinavian coal and steel areas, the big French state monopolies like the production of saltpetre and porcelain and, last but not least, the agricultural societies which were established everywhere on the Continent based on the British model in the second half of the eighteenth century, had an influence on this particular attitude towards chemistry that should not be underestimated.[54] It is remarkable that later on economic theorists and reformers often assigned chemistry to the university subject of economics, after this connection had already been realized in seventeenth-century Sweden, the country of origin of chemical mineralogy and agricultural chemistry, in Stockholm's *Bergskollegium*. Following this example the universities of Uppsala (1750), Lund (1758) and Åbo (1761) had affiliated their new chairs of chemistry to economics, not to medicine, as was usual elsewhere.[55] In Germany, too, such chairs of chemistry were established within newly created cameralist faculties (Gießen 1777, Lautern/Heidelberg 1774, Mainz 1785) or in independent economic institutes (Rinteln and Marburg 1789).

Not least must this institutional development be seen as a consequence of that revaluation of the subject, after which practice was no longer considered as low work, but an application which immediately contributed to general usefulness as the highest social aim. In this way it became possible to declare the subject's innate *utilitas* to be the very proof and measure of its academic *nobilitas*, as Hieronymus David Gaubius had already resolutely done in his *Oratio inauguralis, qua ostenditur, Chemiam artibus academicis jure esse inserendam* of 1731.[56] It is obvious that such an attitude of mind meant that purely speculative curiosity remained suspicious.

> Nous convenons au contraire que la perfection des Arts, la découverte de nouveaux objets de manufacture et de commerce sont, sans contredit, ce qu'il y a de plus beau, de plus intéressant dans la Chymie, et ce qui la rend vraiment estimable. Que seroit-elle en effet sans cela? si ce n'est une science purement théorique, capable d'occuper seulement quelques esprits abstraits et spéculatifs, mais oiseuse et inutile a la société.[57]

It would therefore seem to be in line with the conclusions being presented in this paper that in 1803, at the just refounded Estonian University of Dorpat, the first chair of "theoretical and applied chemistry" was established in the Philosophical Faculty, and the newly appointed professor, Alexander Nikolaus Scherer, addressed his inaugural lecture to the question *In welchem Verhältnisse stehen Theorie und Praxis der Chemie gegeneinander?*[58] His answer was that the opposition between theory and practice could not exist for the chemist, because theory in its true sense was the embodiment of practice; any so-called theory which did not apply to practice was "nicht Theorie, sondern ein Hirngespinst".[59] Scherer, who had managed a stoneware factory near Potsdam till the beginning of his

academic teaching, concluded that it would not be until the contrary view merged into the synthesis of a science applied to the right end that one would get away from:

> dem Vorurtheile, welches bisher alle Theorie gegen sich erweckte, daß sie den höchsten Zweck alles menschlichen Wissens, Gemeinnützigkeit und Anwendbarkeit aufs menschliche Leben, vereitele.[60]

Evidence like these programmatical words of Scherer can be taken as an expression of the intellectual identity or the conscious self-representation of a discipline. But this obviously illuminates only one aspect of the historical process. The historian is still called upon to confront such claims with historical reality. For us, however, such utterances remain invaluable indicators of the spirit of an age, and of the mentalities and motives of its contemporaries, and should therefore be taken into the historical account even if they were mere intentions with only limited immediate practical consequences. For, admittedly, at least in the development of science, consciousness must be counted as a driving force in history.

In this context, the sources cited will have made clear that chemistry of the eighteenth century, in its attempt to achieve support and acknowledgment as a scientific, academic discipline, was forced to see that the traditional distinction between theory and practice was an incriminating heritage. In 1751, when it was for the first time explicitly replaced by the division of the subject into pure and applied chemistry as a symptom of a new understanding of science, chemistry was able to reduce its own aims and its public image to a common denominator with the spirit of the Enlightenment in terms of *utilitas*. This reorientation, which was expressed in the terminological change from theoretical and practical chemistry to pure and applied chemistry, has no doubt contributed to the fact that at the end of the eighteenth century, chemistry enjoyed a wide popularity and received such a rapid, fresh impetus that at last it even acquired the attribute of being the favoured science of its time.[61]

References

1. Schipperges has shown that the distinction was a general, historically almost invariant theme for older medicine. See Heinrich Schipperges, "Die arabische Medizin als Praxis und als Theorie", *Sudhoffs Archiv*, **43** (1959), 317–28; *idem*, "Zum Topos von 'ratio et experimentum' in der älteren Wissenschaftsgeschichte", in: *Fachprosa-Studien. Beiträge zur mittelalterlichen Wissenschafts- und Geistesgeschichte*, ed. by Gundolf Keil, Berlin, 1982, pp. 25–36.
2. See Nicholas Lobkowicz, *Theory and Practice. History of a concept from Aristotle to Marx*, Notre Dame, London, 1967; and for the terminological-historical aspect Lutz Geldsetzer, "'Science' im französischen Sprachund Denkraum", in: *Der Wissenschaftsbegriff. Historische und systematische Untersuchungen*, ed. by Alwin Diemer (Studien zur Wissenschaftstheorie, 4) Meisenheim, 1970, pp. 76–89.
3. See also examples in Eberhard Schmauderer [ed.], *Der Chemiker im Wandel der Zeiten. Skizzen zur geschichtlichen Entwicklung des Berufsbildes*, Weinheim, 1973.
4. Joannes Beguinus, *Tyrocinium Chymicum*, commentario illustratum a Gerardo Blasio, 2nd ed., Amsterdam (1669), p. 2, with the editor's footnote: "Cum experientia practicae veritatem theoriae corroboret, unice verum Chymiatriae studiosum eo allaborandum esse censemus, ut manuali experientiae noctu diuque incumbat, quo tandem dulcissima hujus artis usura frui possit".
5. See Marie Boas, *Robert Boyle and Seventeenth-Century Chemistry*, Cambridge, 1958, esp. pp. 205–8, and more recently Elisabeth Ströker, *Theoriewandel in der Wissenschaftsgeschichte. Chemie im 18. Jahrhundert*, Frankfurt/Main, 1982, pp. 33–42.

6. Previously Hermann Boerhaave, *Sermo academicus de chemia suos errores expurgante*, Leiden, 1718, p. 12 and also [Gabriel François Venel] *Chymie*, in: *Encyclopédie ou dictionnaire raisonné des sciences, des arts et des métiers*, Tome I (Paris 1751), pp. 435–436. For further reference compare also Jost Weyer, *Chemiegeschichtsschreibung von Wiegleb* (1790) *bis Partington* (1970). (Arbor Scientiarum, Reihe A, 3) Hildesheim, 1974, while the Marxist interpretation of the history of chemistry would keep to the dogmatic-systematic separation of theory and practice, as does Wilhelm Strube, *Die Chemie und ihre Geschichte* (Forschungen zur Wirtschaftsgeschichte, 5) Berlin, 1974, and *idem*, *Der historische Weg der Chemie*, Vol. I-II, Leipzig, 1976-1981.
7. For parallels in medicine, see Richard Toellner, "Medicina Theoretica—Medicina Practica. Des Problem des Verhältnisses von Theorie und Praxis in der Medizin des 17. und 18. Jahrhunderts", in: *Theoria cum Praxi. Zum Verhältnis von Theorie und Praxis im 17. und 18. Jahrhundert.* Akten des III. Internationalen Leibnizkongresses, Hannover 1977, Vol. IV: Naturwissenschaft, Technik, Medizin, Mathematik (Studia Leibnitiana Supplementa, XXII) Wiesbaden, 1982, pp. 69–73.
8. Michael Lomonossow, *Elementa chimiae mathematicae* (1741), German in: Michail Wassiljewitsch Lomonossow, *Ausgewählte Schriften*, Vol. I: Naturwissenschaften, Berlin 1961, p. 70.
9. [Pierre Joseph] Macquer, *Dictionnaire de Chymie, contenant la théorie et la pratique de cette science*, 2ième ed., Tome I, Paris, 1778, pp. XXXV–XXXVI: "La théorie ne peut être utile qu'autant qu'elle naît des expériences déjà faites, ou qu'elle nous montre celles qui sont à faire; car le raisonnement est en quelque sorte l'organe de la vue du Physicien, mais l'expérience est son toucher; et ce dernier sens doit constamment rectifier chez lui les erreurs auxquelles le premier n'est que trop sujet. Si l'expérience qui n'est point dirigée par la théorie est toujours un tâtonnement aveugle, la théorie sans l'expérience n'est jamais qu'un coup d'œil trompeur et mal assuré; aussi est-il certain que les plus importantes découvertes que l'on ait faites dans la Chymie, ne sont dues qu'a la réunion de ces deux grands secours".
10. Compare Johann Bartholomäus Trommsdorff, *Versuch einer allgemeinen Geschichte der Chemie*, Erfurt, 1806, part III, pp. 134–146, and especially Ströker (1982, see note 5), pp. 253–98.
11. Kant's *Metaphysische Anfangsgründe der Naturwissenschaft* (1786) in particular and the preface to the second edition of *Kritik der reinen Vernunft* (1787) have strongly influenced chemists' thinking, as in the case of Jeremias Benjamin Richter and especially Friedrich Albrecht Carl Gren.
12. [Pierre Joseph] Macquer, *Élemens de Chymie Théorique*, Paris, 1749; *idem*, *Élemens de Chymie Pratique, contenant la description des opérations fondamentales de la Chymie*, Tome I–II, Paris, 1751. Despite their titles both works are more concerned with facts than theories.
13. Macquer (1749, see note 12), pp. 1–2.
14. Macquer (1751, see note 12), I, Avant-propos.
15. Anton Ridiger, *Systematische Anleitung zur reinen und überhaupt applicirten oder allgemeinen Chymie*, Leipzig 1756, p. 26; see also Christian Ehrenfried Weigel, *Einleitung zur allgemeinen Scheidekunst*, Vol. I–III, Leipzig, 1788–1793, I, p. 92.
16. Daniel Sennert, *De Chymicorum cum Aristotelicis et Galenicis consensu ac dissensu* (1619), in: *Opera*, Vol. I, Lyon, 1656, pp. 181–2.
17. Immanuel Kant, *Metaphysische Anfangsgründe der Naturwissenschaft*, Riga, 1786, Vorrede, p. X, in: *Werke*, ed. by Wilhelm Weischedel, Vol. 8, Darmstadt, 1975, p. 15.
18. Christoph Meinel, "De praestantia et utilitate Chemiae. Selbstdarstellung einer jungen Disziplin im Spiegel ihres programmatischen Schrifttums", *Sudhoffs Archiv*, **65** (1981), 366–89.
19. This aim which exists in all these programmes and especially in chemistry textbooks is particularly clear in Venel's contribution "Chymie" to the *Encyclopedie* (see note 6).
20. Boerhaave (1718, see note 6), p. 2.
21. Hieronymus David Gaubius, *Oratio inauguralis, qua ostenditur, chemiam artibus academicis jure esse inserendam*, Leiden, 1731, p. 7.
22. *Ibid.*, p. 13. 23. *Ibid.*, p. 13.
24. Macquer (1778, see note 9), I, s.v. Chymie, p. 373.
25. Venel (1751, see note 6), p. 408.
26. *Ibid.*, p. 419.
27. Johann Christian Zimmermann, *Allgemeine Grundsätze der theoretisch-practischen Chemie*, Vol. I–II, Dresden, 1755–6, I, p. 2.

28. Johan Georg Menn, *Rede von der Nothwendigkeit der Chemie*, Köln, 1777.
29. F. Vicq D'Azyr, "Éloge de Macquer", in: *Éloges lus dans les séances publiques de la Société Royale de Médecine*, **5** (1785), 45.
30. Jean-Paul Contant, *L'enseignement de la chimie au Jardin Royal des Plantes de Paris*, Cahors, 1952, pp. 42–4.
31. "Discours preliminaire des Editeurs", in: *Encyclopédie* (1751, see note 6), I, p. XIII.
32. [Denis Diderot], "Art", in: *ibid.*, p. 714.
33. Humphry Davy, *A discourse introductory to a course of lectures on chemistry*, delivered in the theatre of the Royal Institution on the 21st of January 1802, in: *The collected works of Sir Humphry Davy*, ed. by John Davy, Vol. II, London, 1839, p. 319.
34. Johann Gottschalk Wallerius, *Bref om Chemiens rätta Beskaffenhet, Nytta och Wärde*, til N. N. öfwersändt, och af honom til Trycket befordradt, Stockholm, Uppsala, 1751.
35. *Ibid.*, pp. 3–4; here taken from an apparently unauthorised and not very reliable translation "Von der Chemie", *Monatliche Beiträge zur Naturkunde*, ed. by Joan Daniel Denso, Berlin, **1** (1752), 61–95, **2** (1752), 161–76; here p. 64. Different, however, in the original: "*Chemia pura* är en Wettenskap om kropparnas blandning, theras principier och grundämnen".
36. The origin of this distinction in the mathematical sciences has not been determined, but there also the division into speculative-theoretical or practical mathematics seems to have been the usual case, as in [Jacques] Ozanam, *Dictionnaire Mathématique*, Amsterdam, 1691, p. 2: "La spéculative ou théorique s'arrête simplement à la conoissance d'une chose. La pratique enseigne à faire et à executer une chose". Later the contrast between *Mathématica pura* ("quae quantitatem absolute consideratam tractat, prout a materia abstrahitur") and *Mathematica mixta* ("in quibus praeter considerationem quantitatis . . . etiam subjectum, cui inest, connotatur"), takes over, as in Johannes Wallis, *Mathesis Universalis* (1657), in: *Opera Mathematica*, Vol. I, Oxford, 1695, and still in the *Encyclopédie*, Tome X, Neuchatel, 1765, pp. 188–9, *s.v.* Mathématique. Christian Wolff remarkably gave equal weight to all four categories, by translating *Mathesis impura sive mixta* by "die angebrachte Mathematick" (Christian Wolff [ed.], *Mathematisches Lexicon*, Leipzig, 1716, col. 866–9), while the later revision of this lexicon clearly favoured the division into "Mathesis pura sive simplex—Mathesis impura vel mixta, die angebrachte Mathematick" in the place of the distinction between theoretical and practical mathematics (*Vollständiges Mathematisches Lexicon*, part I, Leipzig: Gleditsch, 1734, col. 811–15). Here also a similar re-orientation takes places as in chemistry so that in the end Georg Simon Klügel, *Mathematisches Worterbuch*, 1. Abtlg., Vol. III, Leipzig, 1808, *s.v.* Mathematik, only knew the distinction between pure and applied categories.
37. Laurentius Hiortzberg, *Dissertatio chemica de nexu chemiae cum utilitate röipublicae*, praes. Johann Gottschalk Wallerius, Stockholm, 1751.
38. Johann Gottschalk Wallerius, *Chemia physica . . . förestellande chemiens natur* och beskaffenhet, Del I–II, Vol. I–V, Stockholm 1759–1768. In the case of Wallerius and numerous subsequent authors of textbooks, the term "physical chemistry" contained a clear demarcation from the medical-pharmaceutical tradition in chemistry.
39. See esp. Torbern Bergman, *Anleitung zur Vorlesungen über die Beschaffenheit und den Nutzen der Chemie und die allgemeinsten Verschiedenheiten natürlicher Korper*, from the Swedish, Stockholm, Leipzig, 1770, 2nd. ed., Stockholm, Leipzig, 1779; and *idem*, *An essay on the usefulness of chemistry and its application to the various occasions of life*, transl. from the German by Jeremy Bentham, London, 1784.
40. Johann Gottschalk Wallerius, *Physische Chemie, welche von der Natur und Beschaffenheit der Chemie . . . handelt*, from the Latin by Christian Andreas Mangold, Schleusingen, 1772, p. 15.
41. *Ibid.*, pp. 3–11, and also in Wallerius (1751, see note 34), pp. 7–28.
42. Hiortzberg/Wallerius (1751, see note 37), p. 7.
43. Compare in particular Christian Ehrenfried Weigel, *Grundriß der reinen und angewandten Chemie*, Vol. I–II, Greifswald, 1777, to which reference was made by Johann Christian Wiegleb, *Handbuch der allgemeinen Chemie*, Vol. I–II, Berlin, Stettin, 1781, up to Leopold Gmelin, *Handbuch der theoretischen Chemie*, Vol. I, Frankfurt/Main, 1817, pp. 3–4.
44. Johann Christian Polykarp Erxleben, *Anfangsgründe der Chemie*, Göttingen, 1775.
45. Compare Johann Joachim Eschenburg, *Lehrbuch der Wissenschaftskunde. Ein Grindriß encyklopädischer Vorlesungen*, Berlin, Stettin, 1792, § 56, pp. 212–213. An anonymously published

Handbuch der gemeinnützigen Chemie bei verschiedenen chymischen Arbeiten, Leipzig, 1785, divides chemistry without hesitation into learned and useful (pp. 4–5).

46. Weigel (1788, see note 15), I, p. 98. No systematic distinction between these areas was made before André-Marie Ampère, *Essai sur la philosophie des sciences*, Paris, 1834.
47. Michael Lomonossow, *Prodromus ad veram chimiam physicam* (1752–1754), German in: Lomonossow (1961, see note 8), pp. 199–237.
48. Venel (1751, see note 6), pp. 408–37.
49. Geldsetzer (1970, see note 2), p. 83.
50. See also Karl Hufbauer, *The Formation of the German Chemical Community*, Berkeley, Los Angeles, London, 1982, pp. 13–29.
51. Hermann Boerhaave, *Elementa chemiae*, Leipzig, 1732, with elaborate explanation of the usefulness of chemistry in medicine and the mechanical arts (pp. 80–115).
52. Heinrich Jantzen, *Johann Joachim Becher als theoretischer und praktischer Privatökonom*, Ph.D. thesis, Köln, 1925.
53. For the cameralist programme of chemistry in the 18th century, see especially Christian Ehrenfried Weigel, *Vom Nutzen der Chemie insbesondere in Absicht auf Pommern betrachtet*, Greifswald, 1774, pp. 20–21: "Wenn nun die Macht, der Reichthum und der Wolstand eines Staats nach der Menge der begüterten Einwohner desselben geschätzt werden darf, wenn sich selbige auf die häufigere Erzielung, bessere Verarbeitung und einen stärkern Absatz der Landesproducte, auf die daraus erwachsende einträgliche Beschäftigung mehrerer Einwohner, auf einen stärkern Umlauf des Geldes, auf die Verbreitung und Aufnahme des Handels, auf das Uebergewicht der ausgehenden Waaren gegen die einkommenden gründen, die Chemie aber, wie ich es nun kurz erwiesen habe, zu Erreichung dieser Vortheile in mancher Absicht sehr wol angewandt werden kann, ja nothwendig erfordert wird, so muß ein jeder Patriotischer Bürger wünschen, daß sie hier mehr geachter, mehr getrieben, mehr zur Veredlung unsrer Landesproducte angewandt werden möge". Similarly also in Christian Ehrenfried Weigel, *Der Einfluß chemischer Kenntnisse in die Oekonomie, besonders des schwedischen Pommerns*, Greifswald, 1775; G[eorg] A[dolf] Suckow, *Von dem Nuzzen der Chymie zum Behuf des bürgerlichen Lebens und der Oekonomie*, Mannheim, Lautern, 1775; [Johann Georg Pickel], *Von dem Nutzen und Einfluß der Chemie auf das Wohl eines Staats und auf verschiedene Künste und Wissenschaften*, Würzburg, 1785.
54. For a recent study of such influences see Charles Coulston Gillispie, *Science and Polity in France at the end of the Old Regime*, Princeton, N. J., 1980, esp. pp. 50–73, 368–87, 391–413. The similarity in the pattern of institutionalization and the mutual support of chemistry and economics are evident from the still valuable Wilhelm Stieda, *Die Nationalökonomie als Universitätswissenschaft*, Abhandlungen der Kgl. Sächs. Ges. der Wissenschaften, phil.-hist. Klasse, **25** (1906), No. 2.
55. See Hugo Olsson, *Kemiens historia i Sverige intill år* 1800 (Lychnos Bibliotek, 17:4) Uppsala, 1971, pp. 40–51.
56. Gaubius (1731, see note 21), p. 10.
57. Macquer (1778, see note 9), II, pp. 488–9, *s.v.* Laboratoire de chymie; see also Pietro Moscati, *Discorso academico dei vantaggi della educazione filosofica nello studio della chimica*, Milano, 1784, p. 35: "L'impostore fraudolento si contenta del mirabile, l'ozioso contemplatore della sterile curiosità, il filosofo e buon cittadino non dee cercare che l'utile ed il vero".
58. Alexander Nicolaus Scherer, *In welchem Verhätnisse stehen Theorie und Praxis der Chemie gegeneinander?*, Dorpat, 1803.
59. *Ibid.*, p. 14. 60. *Ibid.*, p. 16.
61. See also Karl Hufbauer, "Social Support for Chemistry in Germany during the Eighteenth Century: How and why did it change?", *Hist. Stud. Phys. Sci.*, **3** (1971), 205–31; and Hufbauer (1982, see note 50), p. 29.