The Controversy Between Leibniz and Stahl on the Theory of Chemistry

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During the early modern period, the relation between chemistry and the other disciplines was in a state of flux. Aristotle's matter theories presented in *De generatione et corruptione* and in the *Meteorologica* had been embedded in his overall hylemorphic system. With the breakdown of the Aristotelian system, it became unclear where chemistry belonged and whether it had to borrow its principles from another science or had to establish them by itself. The situation was rendered even more delicate as chemistry could be divided into a theoretical part, which was strongly related to natural philosophy, and a practical part, which qualified more as an art than as a science.

Seventeenth-century textbooks of chemistry usually opened with a theoretical account of matter; but indeed, they very often defined chemistry as an art, not as a purely deductive science in the manner of the Cartesian project.[1] However, as Leibniz often pointed out, building theories in a deductive fashion was useful, since it permitted to capture and organise elements of knowledge that would otherwise remain scattered.[2] In other words, deduction allowed finding general principles under which elements of knowledge were to be structured.[3] Thus, in spite of the eventual difficulty of erecting chemistry on its own principles, there existed a real need, internal to chemistry itself, for a theory that gave a solid account of practice.[4]

The existence of this tension between chemical and physical theories, and between practice and theory, is the reason why the controversy that arose between Gottfried Wilhelm Leibniz (1646–1716) and Georg Ernst Stahl (1660–1734) is so interesting. The crucial questions of the status and role of theories were at stake there, as well as that of the relations that chemistry should or should not keep with other disciplines, and notably with mechanics and medicine. In 1709, Leibniz had read Stahl's major medical work, published the year before, the *True Medical Theory*.[5] He showed himself interested in the insights of Stahl, who was a famous

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chemist and an equally famous professor of medicine at the University of Halle, but at the same time disagreed with numerous theoretical statements contained in Stahl's work. In order to explain his disagreements, he sent a fifteen-page text to Stahl. Stahl answered with a hundred-page text, to which Leibniz replied with approximately thirteen pages. Stahl composed a last answer that was, however, never sent to Leibniz. In 1720, four years after Leibniz's death, Stahl published the whole controversy under the title *Negotium otiosum* (*Idle occupation*).[6]

Disciplinary problems

When Leibniz composed his first set of Doubts concerning Stahl's *Medical Theory*, both men had in common that they had been rejecting a part of Descartes's and the Cartesians' attempts to reduce all phenomena to matter, figure and motion. According to both Leibniz and Stahl, Descartes's knowledge of chemistry was far too weak, and his attempt to subject this discipline to a geometric or mechanical approach could not account for the specificities of the transformations of materials.[7] In other words, both Leibniz and Stahl felt that Descartes did not produce any explanation that was useful to chemists.[8] However, the details of Stahl's criticism were very different from those advocated by Leibniz. Also, while both men rejected the pretensions of iatro-chemistry, they did so for different reasons.[9] According to Stahl, it was not the task of chemistry to explain the phenomena of organised bodies. Furthermore, according to him, medicine was a specific field that does not allow for an interpretation of the changes that take place in non-organic matter. He concluded that "chemistry is completely useless to the true medical theory."[10] This rejection is to be understood as the expression of Stahl's goal of building different sciences, namely chemistry and medicine, on specific and therefore separate grounds.[11]

Leibniz forcefully disagreed with Stahl's double exclusion of chemistry from the medical field, and of physics from chemistry. He subsequently reinterpreted Stahl's achievements in chemistry and in medicine in the light of his own general philosophy in order to render their different approaches to the behaviour of substances compatible. Whereas Stahl's view was disciplinary precisely so as to allow each different specific field to build its own theory based on its specific problems, Leibniz proposed a general viewpoint from which the problems appeared interconnected and in which the criterion of general coherence was of primary importance. As he put it: "Although men conceive parts in it, and give names to these parts in accordance to their commodity, the entire body of the sciences can be considered as the ocean, which is everywhere continuous without interruption or division."[12]

This is the general framework within which will be developed the author's special topic of investigation, namely the notion of chemistry in both Leibniz and Stahl. However, an account is given herein of only a local part of the controversy. This peculiar point concerns the account of matter and of its infinite divisibility—an issue over which Stahl accused Leibniz of making the chemical concept of mixture impossible. Let us note that however local the question of the nature of matter is in the controversy, it is important for the whole discussion because the account of matter partially determines the relation that chemistry and medicine should have. Stahl elaborates an ontological distinction between the structure of chemical matter and the organisation of living bodies, whereas Leibniz postulates micro-organisms in infinitely small entities. This discussion will continue by explaining the contents of both Leibniz's and Stahl's viewpoints on chemistry and will give an account of the relation between divisible or corpuscular matter and of the status of qualities. It will be seen that despite the ambivalence of Stahl's concept of matter, which somewhat oscillates between chemical principles and physical "elements,"[13] the German chemist strongly rejected Leibniz's conception of an infinitely divisible matter. Moreover, it will be shown that in spite of an apparent strong proximity between Leibniz's and Stahl's chemistries, Leibniz's commitment to the idea of an infinite divisibility was seen by Stahl as a serious impediment to the progress of chemical thought. He felt that with his two notions of corpuscles and of infinite divisibility, Leibniz seemed to give with one hand what he took with the other.

Controversy: chemistry and physics (matter, mixture, qualities)

For reasons that will become more explicit later, in an essay included in the introductory part of his *True Medical Theory* and entitled *On the true difference between the mixt and the living body*,[14] Stahl ruled out the idea, shared by Aristotle and Descartes, of the infinite divisibility of matter.[15] Being not chemical but "purely mathematical," this idea had a serious implication for chemical philosophy. According to Aristotle, in a *mixtion*, all the parts of the *mixt* were supposed to be of the same nature, that is, mixed according to the same proportion, however far one divided the *mixt*. There was, in other words, no level at which the *mixt* displayed any heterogeneity. As Stahl wrote:

“[Aristotle] regarded the corporeal *mixtion* as an act or an effect that penetrates so intimately that body to which it belongs that any corporeal particle, *infinitely small*, still keeps, among all the organic varieties, *the same and proportional mixtion* (as one supposes it in animal bodies), whatever the size of the mass and whatever the material quantity and the sensible volume that constitute this body.”[16]

For Stahl, by contrast, a mixture does not have to be identical to all of its components. That is, what *produces* the *mixt* is not the diffusion of the *form* of the *mixt* through the underlying body, but the physical combination of different particles of matter. As a consequence, it would be possible to image a mechanical destruction of a *mixt* by merely retrieving one of its components.[17] From Aristotle’s viewpoint, one must instead *perform an operation* on the *mixt* in order to change its overall form.

Interestingly, from a chemical viewpoint, Leibniz does not appear to have objected to Stahl’s rejection of Aristotle’s concept of *mixtion*, while at the same time affirming both the infinite divisibility of matter and thus the right to view the issue from a “mathematical” perspective. Chemically speaking, the two men would seem to have agreed. Leibniz wrote:

“[Stahl] was right when he noticed the Aristotelians’ mistake who ordinarily think that any part of a *mixt*, however small, can be *mixt* in the same way just as the whole. But certainly, it is neither necessary nor intelligible that after having injected salt into water, its parts are transmuted into a salino-aqueous body, but it is enough that they be diffused throughout the water.”[18]

Such a statement seems to advocate corpuscularism. However, from a “mathematical” perspective, things appear differently. For Leibniz, mathematics is not an essentially separate field of research but belongs to the order of abstraction:

“The mathematical does here only differ from the physical as the mental abstraction does from what is concretely in the things. The mental abstractions do not add something false, but retrieve something true. […] the body is not only infinitely divisible, but actually divided.”[19]

In the abstraction, what is retrieved from the concept of body (or chemical substance) is the fact that in practice, it is difficult to divide, nay impossible. The resulting concept is therefore an infinitely divisible *matter*. Thus, when Leibniz creates such a concept of matter and assesses that this is the true viewpoint on the question, it is also clear that he has erased precisely that element that defines the specificity of the chemist’s activity: the fact that substances have various ways of resisting divisibility. So, “to abstract” might mean that Leibniz has chosen to neglect the practical evidence according to which (in reason, for example, of reversible chemical reactions) there are probably corpuscles, and has consequently posited his concept of matter in an *a priori* approach. Thus, as it is infinitely divisible and in effect actually divided, and having in mind his metaphysical principle of indiscernables which states that no two individual entities can be completely identical, he states that "there is no part of matter in which one will not find numerous varieties."[20] And he added this *argumentum ad hominem*: "Those who are not conscious of that do not pay tribute to Nature's incredible majesty."[21] According to this view, it is false to regard matter as ultimately composed of families of identical constitutive corpuscles. Thus, although Leibniz's chemical concept of mixt presupposes corpuscles, his physical concept of matter abandons them.[22] In turn, if it is clear that according to him, there is no contradiction between physics and chemistry, it is because chemistry simply considers matter from a different perspective than physics.

Despite the fact that on the issue of chemical composition, Leibniz appeared to agree with him, Stahl's reply to Leibniz was quite negative. He stated:

"Once this opinion concerning the absolute divisibility is admitted, any consideration is comprehended under this approach. That is why I strongly persist in saying that this false and miserable presupposition of the *infinite divisibility* has especially prevented *Aristotle's disciples* from reaching a true and positive perception concerning the true reason, *material* as well as *formal*, of *mixtion*, such as that of which we usually conceive the existence. From that was born this confused opinion of the Aristotelians, namely, that *mixtion* constitutes a new *form* that communicates itself to all the *matter* and entirely *changes* it."[23]

Since Leibniz had agreed on the nature of *mixt* bodies, Stahl's insistence may appear odd. After all, Leibniz had acknowledged unchanging corpuscles and a difference between the components of a *mixt* and the *mixt* itself. Did his extremely theoretical, physicalist account of the divisibility of matter really make a difference, and why? According to Stahl, who at this point is surprisingly affirmative as to the possibility of manipulating the constitutive principles of matter,[24] there are good experimental reasons of refusing Leibniz's divisibility: "daily experience testifies that these [material constitutive principles] are close enough and sufficiently often under hand."[25] Of course, what Stahl does not say is how experimentally we would know that these "principles" are constitutive. Besides an "*a priori* reason" that asserts that there is no proof of divisibility, Stahl gives another *a posteriori* reason that consists precisely in what the consequence of infinite divisibility seems to render impossible: the permanency of the "elements," demonstrated by their resistance to a series of testing: "Rather, one finds a fairly consistent magnitude, beyond [which] experience shows that it cannot be rendered any more tenuous."[26]

Two conceptions of chemistry, two conceptions of matter and the qualities

In the introduction, a reminder was given of the commonly perceived need for useful hypotheses and for theories having a strong relation with practice and the chemist's experimental life. It is at this point of the controversy, it is believed, that this need for theories useful to chemistry is the most visible and that one is able to detect a profound difference between Leibniz's and Stahl's respective relation to chemistry. Stahl's response permits one to grasp the nature of the problem: Leibniz's intervention replaces the dual viewpoint (physical and chemical principles) by another one, allegedly better but, through its ontological status, apparently reductionist. Indeed, in Stahl we may observe a hesitation which manifests itself as his oscillating between physical and chemical constitutive principles, where in the first case the viewpoint is more corpuscular (and probably ontological) than qualitative and in the second, more qualitative (and instrumental) than corpuscular. Leibniz, by contrast, zigzags between a physical viewpoint in which the constitutive principles are not material but expressed by forces and a conceptual matter, and a chemical viewpoint where the first elements have an instrumental status or, to be precise, a *derivative* status.[27] At the heart of these theories, in which chemistry seems at risk of being made to depend on physics, stands a no less theoretical issue that has nevertheless a high practical resonance: where to place qualities studied by the chemist and how to think of them?

As far as chemical practice is concerned, it is evident that both Leibniz and Stahl paid a great deal of attention to experimentation and notably to the process of formation of a *mixtion*. In this respect, the situation seems quite straightforward. Both men acknowledged the existence of chemical substances and of instruments (water, air, fire) that could either act chemically or mechanically. Also, they both acknowledged numerous operations such as dissolution, vitrification, sublimation, granulation, fusion and fermentation.[28] As these operations may depend on mechanical, chemical or even on biological causes, distinctions could be drawn between their respective effects and modes of functioning. In turn, in the mind of both scientists, they could also be reduced, according to the mechanistic dogma, to local motion, that is, to the displacement of small particles of matter. Furthermore, for both of them, it was evident that quantities and the substitution of chemicals played an important role in building better explanations of chemical processes. The important point is, however, that although they offered similar explanations for experimental results, that is, although both men might explain an operation by corpuscular means, they differed over the chemical theory itself, in which the experiments and the central notion of quality were embodied.

Stahl: mixtures and primary qualities

To put it in modern language, for Stahl, chemistry as an art can be said to consist in the techniques of analysis and synthesis, which are grounded in the science of the structure of substances.[29] It is therefore a science of mixtures. In Stahl's own words, chemistry is "the Art of resolving *mixt*, *compound*, or *aggregate* Bodies into their *Principles*; and of composing *such Bodies* from those *Principles*."[30] According to him, there are probably four qualitatively different primary principles, namely, three kinds of earths, each being endowed with a specific property, and water. The first earth approximately replaces the former salt principle and has the quality of vitreousness or fusion. The second replaces the former sulphur principle and is actually to some extent Stahl's *phlogiston*; its quality is fat or inflammability. The last earth is the former mercury principle and has the quality of being liquefiable. Above this "atomic" level, there exist several levels of composition. The first is that of the *mixt*, where different principles combine with each other.[31] Given the firmness of the *mixts*, this level of composition actually constitutes yet another atomic level, though not an absolute one. Above that comes the level of the compound bodies. These are made of *mixts* and eventually also of isolated principles. The presence or absence of water in the compounds may determine the degree of resistance of these bodies, which *as mixts* and *as* compounds are too small to be visible. Finally, came the level of the *superdecomposita* or aggregates, which corresponds to our macroscopic level.[32]

And yet, it is at least suggested in both the *Philosophical Principles of Universal Chemistry* and in the Answers to Leibniz that qualities might be caused by physical principles, defined in terms of shaped corpuscles. However, it was also admitted that such constitutive material principles, in spite of the fact that they exist, were not yet known. As to the chemical principles, they are directly related to generic qualities. In the *Philosophical Principles*, chemical principles were presented as uncertain with respect to their reality, but "consider'd only as to their *generical* [sic] *qualities*, they may be allow'd in Compounds." In other words, in compounds, a chemist should be able to find "parts" causing vitreousness while he would find other parts causing fluidity. These qualities are only three in number but besides them, at the levels of *mixts* and compounds, there were stable materials that also present specific sets of qualities whose variations or absence of variation was the object of the chemist's study. In this sense, for example the colour and specific weight of gold constitute the qualities of the *mixt*. Thus, Stahl's reader may observe a progression or derivation in the construction of qualities. However, it is unclear to what extent the primary qualities play a real role in Stahl's practice of chemistry. Still, in the *Philosophical Principles*, their importance was asserted: they seem to be an instrument for the classification of substances and perhaps for predicting possible or impossible operations. It does not seem that "tables of affinities" could have been born out of this research,[33] but another type of "visualisation" might have come to the light: a system of chemical equation which, based on the qualitative composition, would have yielded a synoptic view of the possible analyses and syntheses of the substances.[34] Here, chemistry appears not only as a useful art, but as an art whose progress will be quicker since principle-qualities were sought that would allow predictability and classification. In conclusion, Stahlian chemistry, besides postulating physical principles, intentionally displays a very limited first set of qualities, followed by a less limited set of secondary qualities which each time correspond to particular *mixts* or compounds.

Leibniz: transformations and secondary qualities

Leibniz's concept of matter and therefore of chemistry was more complicated than Stahl's, being intertwined with several other disciplines at the same time. Because of his dynamics, Leibniz thought of matter as being endowed with derivative forces.[35] For this reason, though he regarded matter as infinitely divisible, he could not regard it as undifferentiated.[36] On the contrary, the movements, which always passed through matter, endowed it with a form or some secondary qualities, sometimes also depicted as textures, or as folds,[37] and thus, explains Leibniz's paradoxically corpuscular approach to physical matter.[38] Metaphysically speaking, no sufficient reason for unbreakable atoms could be imagined. Physico-mathematically speaking, however, from the point of view of the calculus and of dynamics, it is meaningful to speak of different corpuscular levels. A degree of firmness being caused by conspiring movements due to the forces internal to matter itself, and there being no reason for either a first (or last) degree of smallness or a first (or last) degree of force, there will always be a material consistent enough (with regard to the force required for its destruction) to be called a corpuscle. These corpuscles, in turn, could together have a conspiring movement that would cause them to assemble into what with regard to the force necessary to destroy it would constitute a bigger corpuscle—and thus *ad infinitum*. To illustrate this with an orthodox Leibnizian example, let us consider a heap of sand of one cubic centimetre and a piece of stone of the same dimensions. One can divide the heap into two parts with a finger, whereas it is clear that one cannot do the same with the stone. From this operational viewpoint, the stone is clearly to be regarded as a corpuscle. However, "for a boat with a given speed, the wave becomes as hard as a marble wall."[39] It is clear that the resistance will be extremely different and could result in the destruction of the boat, and in that of the wave. This suggests that for Leibniz, the "physics of materials" is a discipline that studies the transformations of matter.

However, he did not charge his physics with the task of replacing chemistry, which he defined as follows: "of the predicates there exists a science of qualities, [to show] how we find the subjects in which the qualities are found. To this belongs chemistry."[40] The corpuscles are not "atoms," and this is so for two reasons: strictly speaking, atoms are regarded as containing no inner part that would be of a nature different from that of the whole, a view that Leibniz cannot accept; also, bodies are only atomic with respect to our current inability to destroy them. Nor are corpuscles merely *instrumental and logic*, because they empirically exist, which indeed bestows a degree of *reality* upon them.

But then, what kind of chemistry will this be, of which Leibniz says that it belongs to a science of qualities (*poiographia*), and what is its status? As to its epistemic status, Leibniz is very clear: "indeed, chemistry will be the practical part of general physics, and in the same way as medicine is related to man and agriculture to plants, so chemistry is related to elements and bodies, either of the same type or roughly mixed."[41] "Practical," as distinguished "theoretical," here means *contingent* and this is so precisely because chemistry belongs to a "poiographia." Indeed, the qualities have to be regarded as either primary or secondary. Those qualities which in chemistry allow to evaluate the transformations of matter and whose production is *in fine* also one of the goals assigned to chemistry, are the secondary (or derivative) ones, the primary qualities being extremely few in number and belonging to physics. The qualities are what an observer can feel from the object of his senses. Their contingency is due to their sensible origin. Leibniz cited Democritus's and Leucippus's adage with approval that "qualities come from opinion and are rather *viewpoints on things*, not things themselves."[42] As such, the idea of the particular qualities that we encounter in our relation to things, although also dependent on the conditions of observation, nevertheless have some stability and should allow us to conduct efficient proofing of materials.[43] In turn, chemistry produces real transformations and is also at the origin of true knowledge: when a chemist affirms that there is a substance like gold, he is certainly right; when the chemists' categories allow for classifications of materials, they bring answers that will receive a better explanation when translated into the language of physics, but that remain nevertheless true. Let us note that though chemical activity is described as sensory[44] and contingent, this does not mean that this is untrue, and even less that physics could achieve, in Leibniz's eyes, a better result.

Thus, both Leibniz and Stahl acknowledge corpuscles and their conservation in a hidden state in mixtures (whether they be *mixts* or compounds does not really matter here) and there is, generally speaking, no strong difference between their respective views on the practice of chemistry. Both men regarded qualities and their variations in the course of varied experimental operations as a heuristic criterion for the evaluation of the composition of mixtures. Indeed, both of them thought that these qualities were not primary in substances, movement and figure constituting a more fundamental *explanans*—although Leibniz, with his concepts of conspiring movement, diffusion and alteration, suggested an even more fundamental level of explanation.[45]

Conclusions

To conclude, it is useful to underline two differences. The first the allows formulation of a hypothesis as to Leibniz's and Stahl's respective relations to Cartesianism. The second provides the reason for why it can be believed that Stahl was right in rejecting Leibniz's appropriation of chemistry.

Surprising as it may seem, it seems that Stahl's theory of chemistry was slightly more Cartesian than was Leibniz's. In the context of his atomism, which within the limits of its theoretical scope, it has been taken to have been more realist than merely instrumental, Stahl seems to have thought that the properties of substances should be explained through movement and figure, it being understood, with Descartes, that motion does not belong to the substance but originates from outside. Leibniz, by contrast, despite his acceptance of movement and figure, additionally also injected the concept of forces (although derivative ones[46]) *into* the material substances themselves.

As to the second conclusion, it seems that Stahl's refusal of Leibniz's definition of chemistry was less due to pure *a priori* reasons than to the fact that the theory of infinite divisibility put at risk his *a posteriori* theoretical construction of the structural levels of matter. This theoretical construction, which could distinguish between a *mixt*, a compound and an aggregate, was useful, as explained earlier, in distinguishing chemical from mechanical composition and was thus also related to the classification of operations and of qualitative change. Hence, by considering matter as liable not so much to different levels of organisation but rather to different levels of firmness, that was, by suggesting that there were corpuscles contained in corpuscles, Leibniz probably complicated the work of the chemist, which was aided by the theory of the structural levels. In fact, Leibniz did not seem to regard chemistry as dealing with structures at all: "all bodies belong to chemistry […] if treated not as structures but as masses."[47] Stahl could agree with this at most partially, as he regarded the determination of the modes and levels of mixture (each possessing a distinct name: combination; union; juxtaposition) as a relevant task of the chemist.[48] These structural concepts seem to have been weakened by Leibniz's theory, which undermined their general validity, restricting it to practice. The most interesting feature of this point of the controversy between Leibniz and Stahl is perhaps that the motive of Leibniz's opposition lay hidden in what distanced him the most from Stahl, namely his actually infinitely divided matter (together with what Stahl felt to be "vague" practical statements), whereas Stahl seemed to advocate the heuristic value of a theory of which he elsewhere acknowledged its uncertainties.

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References and end-notes

[1] Consult for example Nicaise Lefebvre, *Traité de la chymie* (Paris: Thomas Jolly, 1660); Christophle Glaser, *Traité de la chymie* (Paris: Jean Dhoury, 1672). Same type of definition in Georg Ernst Stahl, *Philosophical Principles of Universal Chemistry*, ed. Peter Shaw (London: John Osborn & Thomas Longman, 1730). See the extended treatment of this question in Antonio Clericuzio, *Elements, Principles and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century* (Dordrecht, Boston, London: Kluwer Academic Publishers, 2000).

[2] See, for example, Leibniz's criticism of Boyle in the letters exchanged between Huygens and Leibniz following Boyle's death, of 4 February 1692 and 9/19 February 1692 respectively (Gottfried Wilhelm Leibniz, *Der Briefwechsel mit Mathematikern*, ed. Carl I. Gerhardt (Hildesheim: Georg Olms, 1987), 687-90) see also Leibniz's correspondence with the chemist Johann Andreas Stisser (see Leibniz, *Opera omnia*, ed. Ludovicus Dutens (Hildesheim: Georg Olms, 1989), vol. 2, part 2, 122 ff.). On the usefulness of the elaboration of theories in relation to

the problem of matter and of chemistry, see Leroy E. Loemker, "Boyle and Leibniz," *Journal of the History of Ideas* 16 (1955): 22-43 and Salvatore Russo, "The Concept of Matter in Leibniz," *The Philosophical Review* 47 (1938): 275-292. For the Leibnizian "reinterpretation" of Boyle, see Clericuzio, *Elements, Principles and Corpuscles*, 104.

[3] Leibniz always said that the "discovery" of the laws of dynamics was made through a metaphysical inquiry. For example, see *Discours de métaphysique*, § 21 in Gottfried Wilhelm Leibniz, *Die philosophischen Schriften*, ed. Carl I. Gerhardt (Berlin: Weidmann, 1875–1890), vol. 4, 427-63.

[4] Concerning the problem of the proliferation of scattered or rivalling pieces of knowledge in chemistry, see Bernadette Bensaude-Vincent, Isabelle Stengers, *Histoire de la chimie* (Paris: La découverte, 2001), 56-8 and 63-5.

[5] The *True Medical Theory* or *Theoria medica vera* is a collection of Stahl's medical publications preceded by several introductory parts in which Stahl set out the fundaments of his medical theory. The edition used here is the 19th-century French translation by Théodose Blondin (Georg Ernst Stahl, *Œuvres médico-philosophiques et pratiques*, ed. Théodose Blondin (Paris, Montpellier, Strasbourg: J.-B. Baillière et fils, Pitrat et Cie, Treuttel et Wurtz, 1859–1864), 7 vol.). In the course of the controversy, Leibniz mostly attacked the introductory treatises. For a detailed although incomplete bibliography of Stahl's works, see James R. Partington, *A History of Chemistry* (London & New York: Macmillan & St. Martin's Press, 1961–1972), vol. 2, 655-62.

[6] Stahl, *Negotium otiosum seu Skiamaxia […]* (Halae: Litteris Orphanotrophei, 1720). A partial English translation and summary are provided in L. J. Rather, J. B. Frerichs, "The Leibniz-Stahl Controversy—I. Leibniz' Opening Objections to the *Theoria medica vera*," *Clio Medica* 3 (1968): 21-40 and Rather, Frerichs, "The Leibniz-Stahl Controversy—II. Stahl's Survey of the Principal Points of Doubt," *Clio Medica* 5 (1970): 53-67. As to the Leibnizian part of the controversy, I have made use of the edition, translation and commentaries by Sarah Carvallo (*Controverse sur la vie, l'organisme et le mixte* (Paris: Vrin, 2004)). As to Stahl's part, I refer to Blondin's French translation (vol. 6 of the *Œuvres médico-philosophiques et pratiques*).

[7] The relation of both Leibniz and Stahl to Cartesianism is in fact not straightforward, since in both cases, it changed with time. Although he refused to define himself entirely as a Cartesian, the young Leibniz made use of Descartes's shaped corpuscles (Letter of Leibniz to Jakob Thomasius of 30 April 1669, in Leibniz, *Philosophische Schriften*, vol. 6). Similarly, the young Stahl made use of shaped corpuscles (see Ku-Ming (Kevin) Chang, "Fermentation, Phlogiston and Matter Theory: Chemistry and Natural Philosophy in Georg Ernst Stahl's *Zymotechnia Fundamentalis*," *Early Science and Medicine* 7 (2002): 31-64, on 37) and he even attempted to develop visual models that may recall Descartes's (see Georg Ernst Stahl, *Fundamenta chymiae dogmaticae et experimentalis* (Norimbergae: Impensis B. Guolfg. Maur. Endteri consortii et Vid. B. Iul. Arnold Engelbrechti, 1747), vol. 3, 15 and 43). Equally, both Leibniz's and Stahl's relation to *chymistry* (see William R. Newman, Lawrence M. Principe, "Alchemy vs. Chemistry: The Etymological Origins of a Historiographic Mistake," *Early Science and Medicine* 3 (1998): 32-65), is not straightforward either. Although interested by the Cartesian approach to matter, the young Leibniz also showed interest in a more hermetic "chymistry" (see Georges M. Ross, "Leibniz and the Nuremberg Alchemical Society," *Studia Leibnitiana* 6 (1974): 222-48, which shows how unclear Leibniz's affiliation with Rosicrucianism was, but also how Leibniz indeed worked on "alchemical" topics). The young Stahl appears to have believed in the realisation of the philosopher's stone and in chrysopoeia (see Kevin Chang, "Georg Ernst Stahl's Alchemical Publications: Anachronism, Reading Market, and a Scientific Lineage Redefined," in *New Narratives in Eightenth-Century Chemistry*, ed. L. M. Principe (Dordrecht: Springer, 2007), 23-

44). In the period of the controversy, it appears that both Leibniz and Stahl were occupied with building a more personal approach to chemistry that went beyond a mere affiliation with mechanism or "alchemy" or, in the case of Leibniz, had erected a theoretical construction in line with his more general philosophical thought. For a general refutation of early 18th-century chemistry seen as affiliated with either Cartesianism *or* Newtonianism, see Lawrence Principe's claim that chymistry was far less dependent on Descartes's or Newton's theories than presumed in the earlier historiography of chemistry (Lawrence M. Principe, "A Revolution Nobody Noticed? Changes in Early Eighteenth-Century Chymistry," in *New Narratives in Eightenth-Century Chemistry*, 1-22).

[8] "Mons. des Cartes ignoroit la chymie sans laquelle il est impossible d'avancer la physique d'usage. Ce qu'il dit des sels fait pitié à ceux qui s'y entendent, et on voit bien qu'il n'en a pas connu les differences." (Leibniz, *Philosophischen Schriften*, vol. 4, 302). However, in other circumstances, as when he criticized Boyle's lack of theorization, Leibniz could also celebrate Descartes's attempts at including chemical changes in his physics (see the letter to Huygens of 9/19th February 1692 in Leibniz, *Briefwechsel mit Mathematikern*, 690). As to Stahl, see Hélène Metzger, "La philosophie de la matière chez Stahl et ses disciples," *Isis* 8 (1926): 427-64, on 429-34.

[9] It is reasonable to say that Stahl's rejection of iatro-chemistry is not always clear (see Hélène Metzger, *Newton, Stahl, Boerhaave et la doctrine chimique* (Paris: Félix Alcan, 1930), 114 ff. and Chang, "Fermentation, Phlogiston and Matter Theory," 31-64).

[10] Cited in Metzger, "La philosophie de la matière," 439.

[11] Here I must consider two opposite views of Stahl's concept of matter: that of Hélène Metzger, who regards Stahl's matter as active, and that of Kevin Chang, who tends to qualify it as inactive (in spite of the ambiguities contained in Stahl's early theories). Compare Metzger, "La philosophie de la matière," 439-40 with Chang, "Fermentation, Phlogiston and Matter Theory," 57-59.

[12] "Le corps entier des sciences peut estre consideré comme l'ocean, qui est continué partout, et sans interruption ou partage, bien que les hommes y conçoivent des parties, et leurs donnent des noms selon leur commodité." (Gottfried Wilhelm Leibniz, *Opuscules et fragments inédits*, ed. Louis Couturat (Hildesheim: Georg Olms, 1961), 530).

[13] The expression "physical elements" is perhaps abusive. Indeed, Stahl usually distinguished between chemical and physical *principles*. Inasmuch as they are physical, the principles refer to juxtaposition or apposition, whereas as chemical, they connote the operations to be performed in order to obtain principles from substances or substances from principles (see Stahl, *Fundamenta chymiae dogmaticae et experimentalis … Editio secunda … Pars I* (Norimbergae: Impensis B. Guolfg. Maur. Endteri consortii. et vid. B. Jul. Arnold. Engelbrechti, 1746), 3-4, or Stahl, *Philosophical Principles of Universal Chemistry*, 4).

[14] *De mixti et vivi corporis vera diversitate* (*Œuvres médico-philosophiques et pratiques*, vol. 2).

[15] In fact, as Leibniz remarked, Aristotle did not regard matter as infinitely divided. Here Stahl commits a error of interpretation (see Leibniz's "Doubt XVII" and Sarah Carvallo's note 43 in *Controverse sur la vie*, 171).

[16] "Le chef de l'école péripatéticienne regardait, la mixtion corporelle comme un acte ou un effet qui pénètre si intimement ce corps auquel elle est échue en partage, que toute particule corporelle, *infiniment petite*, conserve encore, au milieu de toutes les variétés organiques, *une même et toujours égale mixtion* (telle qu'on la suppose dans le corps animal), quelle que soit la grandeur de la masse, quels que soient aussi la quantité matérielle et le volume sensible qui constituent ce

même corps." *Du mixte et du vivant*, § 2, in Stahl, *Œuvres médico-philosophiques et pratiques*, vol. 2, 256.

[17] See *Du mixte et du vivant*, § 4, in Stahl, *Œuvres médico-philosophiques*, vol. 2, 257. In this text, Stahl considers this possibility, but excludes it. It would be consistent to believe that a mixt could be mechanically cut into its parts, while a chemical operation would be required that separate it into its *constituent* parts.

[18] "Illud recte notatur, falsum esse, quod Aristotelici vulgo sibi persuadent, partem mixti, quantum vis parvam, eodem modo mixtam esse posse, ut totum. Certe sale in aquam injecto non est necesse, (imo nec intelligibile) ut partes ejus transmutentur in corpus aqueo-salinum, sed sufficit, ut dispergantur per aquam." Leibniz, "Doubt XVII," in *Controverse sur la vie*, 94-5.

[19] "Mathematicum hic a physico non differt, nisi ut abstractum animo a concreto rebus. Abstrahentes animo non aliquid falsi afferunt, sed aliquid veri seponunt […] nec tantum divisibile est corpus in infinitum, sed et actu divisum." Leibniz, "Doubt XVII," in *Controverse sur la vie*, 92-3.

[20] "[…] ita, ut nulla sit pars materiae, in qua non multas rursus varietates notare liceret."

[21] "Qui haec non animadvertit, parum assurgit ad incredibilem naturae majestatem."

[22] That is why Sarah Carvallo writes: "La notion d'élément reçoit alors un sens non plus ontologique, mais à la fois expérimental et logique" (*Controverse sur la vie*, 37).

[23] "[…] siquidem stabilita opinione de *divisibilitate in infinitum* absoluta, haec omnes respectus sub se complectitur. Unde iterum iterumque insisto dicere et asseverare, quod proprie haec perversa praesuppositio *de divisibilitate in Infinitum* obstiterit *Aritotelicis*, quo minus ullum realem et solidum conceptum haurire potuerint de vera tam *materiali*, quam *formali* ratione *Mixtionis*, uti vere fieri solere percipitur. Hinc enim unice quasi manifestum est […] enatam esse confusam illam sententiam omnium Aristotelicorum, quod Mixtio ita novam *formam* constituat, quae totam *materiam* informet, et secundum totum *immutet*, ut tota *aequaliter* sit illud novum, quod nunc est." Stahl, *Negotium otiosum*, 67.

[24] Some years before, Stahl showed greater scepticism with regard to the possibility of knowing the constitutive elements, writing: "Those are called Physical Principles whereof a Mixt is really composed; but they are not hitherto settled," Stahl, *Philosophical Principles*, 4.

[25] "[…] sed experientia indies testatum faciat, quod illa [constitutiva materialia principia] satis prope, & affatim passim, ad manus sint." Stahl, *Negotium otiosum*, 66.

[26] "Quia experientia nusquam ullum specimen suppedidat, quod tale quidquam actu fiat aut existat, ut, inquam, Mixta, etiam sub immensa dissolutione diminutiva, inveniantur. Sed vel satis crassam tueantur magnitudinem, ultra quam se extenuari non ferunt, experientiae suffragio […]" Stahl, *Negotium otiosum*, 66.

[27] Whereas matter is infinitely divisible, forces are nevertheless at the origin of corpuscles. Leibniz wrote: "Et je m'imagine que si cela [the presence of "metaphysical" forces in matter] estoit plus connu, ou mieux consideré, bien des personnes de piété n'auroient pas si mauvaise opinion de la Philosophie Corpusculaire," "Extrait d'une lettre de Mr. de Leibniz, sur la question, si l'essence des corps consiste dans l'étendue," in Leibniz, *Philosophische Schriften*, vol. 4, 466.

[28] However, they could disagree as to the precise effect of these operations, as in the case of fermentation (see Carvallo, *Controverse sur la vie*, 37-41).

[29] In this sense, there is a (relative) continuity with Paracelsus's view on chemistry. By speaking of analysis and synthesis Stahl knew that he referred to Paracelsus's "spagyrical philosophy" (a science of analysis and synthesis). (For the meaning of "spagyrism" see Peter Alexander, *Ideas, Qualities and Corpuscles: Locke and Boyle on the External World* (Cambridge: Cambridge

University Press, 1985), 15 and William Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: The University of Chicago Press, 2006), 45.)

[30] Stahl, *Philosophical Principles of Universal Chemistry*, 1.

[31] Between the *Fundamenta chymia* and *De mixti et vivi corporis vera diversitate*, there is no difference: a mixt is defined as composed of principles.

[32] The fact that there is a difference between a mixt, a compound, and an aggregate is important because it allows to conduct research into the question of the difference between homogeneous and heterogeneous bodies and because it allows to establish a practical separation between the chemical and mechanical operations that are performed (see Stahl, *Philosophical Principles*, 12, 21-6, 58-63).

[33] See Isabelle Stengers, "L'affinité ambiguë: le rêve newtonien de la chimie du XVIIIe siècle," in *Éléments d'histoire des sciences*, ed. Michel Serres (Paris: Bordas, 1989), 297-319 on 303, 305, 314.

[34] An article by David Oldroyd consisting in a reading of Peter Shaws's translation of Stahl, arrives at conclusions that emphasize the importance of having chemical elements endowed with qualities and taking operations into account (David Oldroyd, "An Examination of G. E. Stahl's *Philosophical Principles of Universal Chemistry*," *Ambix* 20 (1973): 36-52).

[35] The question of the integration of Leibniz's chemistry into his own general philosophy is discussed by Sarah Carvallo, *La controverse sur la vie*, 34-37.

[36] See the "Animadversiones in partem generalem Principiorum Cartesianorum" and "De ipsa Natura," in Leibniz, *Philosophische Schriften*, vol. 4, 388 and 514, respectively.

[37] For Gilles Deleuze, the metaphor of "fold" is representative of all of Leibniz's thought (Gilles Deleuze, *Le pli, Leibniz et le baroque* (Paris: Les éditions de minuit, 1988)). Thus, when he had to explain the "division of the continuous," Leibniz used the image of a piece of fabrick where there were folds in which one could always find smaller folds ("[…] ut chartae vel tunicae in plicas, itaque licet plicae numero infinito, aliae aliis minores fiant […]" Leibniz, *Opuscules et fragments inédits*, 615).

[38] See also Leibniz, *Nouveaux essais sur l'entendement humain*, book 2, ch. 23, § 23 in *Philosophische Schriften*, vol. 5.

[39] "A une certaine vitesse du bateau, l'onde devient aussi dure qu'un mur de marbre." Deleuze, *Le pli*, 8. I have not been able to find a similar statement in Leibniz himself and this is Deleuze's interpretation of Leibniz's physics, which I believe is entirely right.

[40] "Praedicatorum est poiographia, ut experiamur in quibus subjectis reperiantur qualitates. [Et huc chymia.]" Leibniz, *Opuscules et fragments inédits*, 526.

[41] "Equidem si Physicam illam appellemus generalem, quae communia tribus regnis tractat, profecto Chemia erit practica pars Physicae generalis, et uti Medicina ad hominem, aut agricultura ad plantas, ita sese Chemia ad elementa et corpora, vel similaria vel rudius mista, habebit […]" Letter to Stisser, 25 May 1700 in Leibniz, *Opera omnia*, vol. 2, part 2, 128.

[42] Paraphrase of "Primus Democritus quod constet, cum Leucippo purgare Physicam conatus est a qualitatibus αρρητοις, dixitque ποιοτητας νομωι ειναι, qualitates esse ex opinione, quasi in speciem, non veras res." "Antibarbarus physicus pro Philosophia Reali contra renovationes qualitatum scholasticarum et intelligentiarum chimaericarum," in Leibniz, *Philosophische Schriften*, vol. 7, 343.

[43] See for example Leibniz, *Nouveaux essais*, book 2, ch. 29, § 4.

[44] This is Pierre Laszlo's expression, in *La parole des choses* (Paris: Hermann, 1993).

[45] This view is sketched in a text of 1702 and in "De ipsa Natura," written in 1698 (see Leibniz, *Philosophische Schriften*, vol. 4, 393-400 and 504-16).

[46] The distinction between primitive and derivative forces corresponds to the distinction between spiritual and material worlds: a substance of a kind cannot modify a substance of the other kind. Therefore, in the material world, there are only derivative forces, whereas the spiritual world contains beings (monads) possessing primitive forces (see *Philosophische Schriften*, vol. 2, 251, 262; vol. 3, 457; vol. 6, 150). Leibniz's materials are not active, since movement is always caused by surrounding materials, but Leibniz's materials, which always include inner materials, can be *regarded* as active (though not intrinsically but derivatively). For a detailed discussion on Leibniz's concept of forces, consult Daniel Garber, "Leibniz: Physics and Philosophy," in *The Cambridge Companion to Leibniz*, ed. Nicholas Jolley (Cambridge: Cambridge University Press, 1995).

[47] "Imo corpora omnia ad Chymiam pertinent, quando secundum operationes physicas, insensibili processu constantes, non ut structurae, sed ut massae tractantur." Leibniz, "Doubt XII," in *Controverse sur la vie*, 90.

[48] By contrast, I am not sure that Leibniz really took this type of difference into account. In his reply to Stahl's answer, and notably from an example that he adduced, I believe that he did not distinguish between the model of mixtion and that of aggregation (see Leibniz, "Reply XVII," § 3 in *Controverse sur la vie*, 118. For the distinction between mixtion and aggregation and whose return to Aristotle with the differentiation between the mixtion of sugar into water and the juxtaposition of grains, see also Pierre Duhem, *Le mixte et la combinaison chimique: essai sur l'évolution d'une idée* (Paris: Fayard, 1985), part 1, ch. 1).