III

Papers and Posters

Did Lucretius' Atomism Play any Role in Early Modern Chemistry?

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Recent historiography has pointed out the influence on early modern chemistry of different classical theories of matter. Among these the reading and interpretation of the writings of Lucretius is a particularly interesting example. While the *De rerum natura* has been regarded by religious authorities as a dangerous heterodox work, chemists throughout Europe between 1500 and 1800 became progressively interested in adopting Lucretius' qualitative atomism. It is argued that such atomism played an important role not only in building an alternative philosophy of matter to that of Aristotle, but also in developing more concrete and operative options, such as the definition of chemical reaction.

"So different forms come together into one mass and things are made of mixed seeds *[permixto semine]*. Nay more, everywhere in these very verses of mine you see many letters common to many words, and yet you must needs grant that verses and words are formed of different letters, one from another; not that but a few letter run through them in common, or that no two of them are made of letters all the same, but that they are all alike the same one with another. So in other things likewise, since there are atoms common to many things, yet notwithstanding they can exist with sums different from one another; so that the human race and corn and glad trees are rightly said to be created of different particles". *DRN*, II, 686-699.[1]

By taking the fortunate analogy between atoms and letters, already used by Democritus, Lucretius wished to push it further and aimed at bringing the tenent of classical atomism from the relevance attributed by Democritus to individual atoms to the central importance he attributed to aggregates and combinations. Lucretius thought that the macroscopic bodies were the results of the combination of molecules (which he called *concilia*) constituted of different kinds of atoms. While the number of atoms existing in nature was infinite, their forms, just like the letters of the alphabet, were limited. These very forms were at the end the explanation of the macroscopic differences between different observable bodies:

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"Why? Unless it be that those bodies of light are smaller than those of which the quickening liquid of water is made. And we see wine flow through the strainer as swiftly as you will; but, on the other hand, the sluggish olive-oil hangs back, because, we may be sure, it is composed of particles either larger or more hooked [*magis hamatis*] and entangled [*plicatis*] one with the other…

So that you may easily know that those things which can touch the senses pleasantly are made of smooth and round bodies [*levibus atque rotundis*] but that on the other hand all things which seem to be bitter and harsh, these are bound together with particles more hooked…". *DRN*, II, 389-394 and 402-407.

Lucretius defined in further details the relations between the shapes of the atoms and their physical-chemical effect:

"Other particles there are, moreover, which cannot rightly be thought to be smooth not altogether hooked with bent points, but rather with tiny angles standing out a little, such as they can tickle the senses rather than hurt them; and of this kind is lees of wine and the taste of endive. Or again, that hot fire and cold frost have particles fanged [*dentata*] in different ways to prick the senses of the body is proved to us by the touch of each…". *DRN*, II 426-434.

As their shapes were limited, the same kinds of atoms could enter into the composition of completely different bodies, like letters in words. The macroscopic changes were due to the different dispositions of the same atom, just like the letters which compose the word *AMOR* might be rearranged and result into the word *ROMA*. However, the analogy stopped here, because the atoms could be rearranged not only horizontally but in all three dimensions. Lucretius' description of this kind of arrangement is worth quoting:

"In truth when you have tried all those parts of one body in every way, shifting top and bottom, changing [*transmutans*] right with left, to see what outline of form in that whole body each arrangement gives…". *DRN*, II, 487-90.

It is interesting to note that in this important quotation Lucretius introduced the term transmutation, for the first time, into the Latin language. However, while later alchemists understood under this concept the possibility to obtain gold from lead through a complex experimental procedure, Lucretius understood it as the effect of the molecular structure of bodies which, under certain circumstances, suffered changes into the disposition of their atoms without their quantity or quality being minimally altered.

Equally original is the use that Lucretius makes of the term mixt (*permixtum*). In contrast to the reductionistic philosophies of matters set forth by the pre-Socratic philosophers and by Aristotle, Lucretius thought that matter was mostly constituted by molecular aggregates and that the motion of isolated atoms was only a temporary state which inevitably led to some kind of combinations with other atoms:

"There is not one of all the things, whose nature is seen before our face, which is built of one kind of atoms, nor anything which is not created of well mixed seeds [*permixto semine constet*]; and whatever possesses within it more forces and powers, it thus shows that there are in it most kinds of atoms and diverse shapes." *DRN*, II,583-588.

This is a crucial statement, because Lucretius while recognising the intrinsic complexity of matter, could explain phenomena such as the passage from the inorganic to the organic and *vice versa* from life to death, without having to resort to metaphysical or occult causes. When the molecule of a body dissolved the atoms did not disappear but moved to form other molecules, not necessarily the same, and thus continue the eternal cycle of the transformation of matter.

It is now important to underline the difference of Lucretius' concept of a mixed body with that supported by Aristotle in *De generatione et corruptione* (327a-b) where he excluded, in the following passage, the possibility of the ingredients to maintain their original identity:

"According to some thinkers, It is impossible for one thing to be combined with another. They argue that if both the combined constituents persists unaltered, they are no more combined now than they were before, but are in the same condition: while if one has been destroyed, the constituents have not been combined –on the contrary, one constituent is and the other is not, whereas combination demand uniformity of condition in them both: and on the same principle even if both the combining constituents have been destroyed as the result of their coalescence, they cannot have been combined since they have no being at all."[2]

Aristotle, it is clear from this passage, preferred to study the qualitative transformation of matter only from its observable features. Lucretius, on the contrary, is interested more in the chemical mechanism of combination that in its effects. The weaknesses of this approach laid in the impossibility of empirical verification. However, while for the Aristotelians mixts were essentially different from the sum of their constituents, for Lucretius the atomic composition of matter allowed the reversibility of molecular combinations and the whole universe was nothing else than a perennial flow of dissolutions and combinations of atoms the sum of which remained constantly and eternally the same. From this followed the basic principles stated in the first book of the *DRN* which say that "nothing is ever begotten of nothing" (I, 149) and that "nature breaks up each thing again into its own atoms, nor does she destroy ought into nothing" (I, 215-216).

From this succinct exposé it is hopefully clear how fecund the Lucretian view of matter could have been if applied to the solution of chemical issues. It is therefore difficult to agree with the conclusion of the recent book on atomism by William Newman[3] where the success of corpuscularism is traced back to the fourth book of Aristotle's *Meteorologica* rather than to classical atomism. But this is another story.

Having briefly exposed the basic principles of Lucretius' philosophy of matter, their influence on early modern chemistry will now be highlighted.

The first commented edition of Lucretius' poem appeared in 1511 (Bologna)[4] but prior to that, Leonardo da Vinci had showed, in a chemical context, a confident knowledge of its contents and used the term *semenze delle cose* (seeds of things), *attomi* (atomi), *particule* (particles) which he took from both Lucretius' *DRN* and the Latin translation of Diogenes Laertius *Vitae philosophorum*. An acquaintance of him, the artillery officer from Siena Vannoccio Biringuccio, author of the *De la pirotechnia* the first systematic survey of the mineral world (published in Venice in 1540) also showed some acquaintance with the poem when, in order to explain the different texture of silver mines, resorted to the hypothesis of the different shape of the atoms and *particelle*.

It was during the seventeenth century that Lucretius was discovered by naturalists in general and chemists in particular as an effective source in the battle against Aristotle's theory of matter.

In 1620 in the second part of the *Novum Organum* Francis Bacon while describing the shape of the particles which constitute the texture of matter wrote the following:

"Thus let the nature in question be the Expansion or Coition of Matter in bodies compared one with the other; viz. how much matter occupies how much space in each. For there is nothing more true in nature than the twin propositions, that "nothing is produced from nothing" [*ex nihilo nihil fieri*][5] and "nothing is reduced to nothing" [*neque quicquam in nihilum redigi*][6], but the absolute quantum or sum total of matter remains unchanged, without increase or diminution."[7]

Here Bacon quotes nearly verbatim Lucretius' principle of conservation of matter and from it he deduces some important consequences also for chemistry:

"this greater or less quantity of matter in this or that body is capable of being reduced by comparison to calculation and to exact or nearly exact proportions.

Thus one would be justified in asserting that in any given volume of gold there is such an accumulation of matter, that spirit of wine, to make up an equal quantity of matter, would require twenty-one times the space occupied by the gold.

Now the accumulation of matter and its proportions are made manifest to the sense by means of weight.".[8]

Epicurus and Lucretius were the first atomists to attribute a specific weight to atoms, a feature which was destined to be of crucial importance for chemists.

Bacon, as it is well known, favoured the circulation of Lucretius' atomism within English scientific circles and its success among the future founders of the Royal Society of London is testified to by the first English translation of the first book of the *DRN* which was carried out in 1656 by John Evelyn.[9] In addition to the influence of Bacon, the edition of the *DRN* published by Gassendi in 1649 and then, less complete, in 1658 (see notes 11 and 12), played a central role in the appreciation of scientists in general and chemists in particular of the contents of the poem. In fact was Gassendi who tried the first serious attempt to combine chemical conceptions with atomism[10] and Lucretius' qualitative approach to the substratum of matter seemed indeed particularly fitted to bring such an attempt to a successful conclusion. The first reason that made atomism attractive was the patent observation made by seventeenth century chemists that the four elements of Aristotle and the three principles by Paracelsus were no longer sufficient to explain the complex texture of matter and the innumerable variety of macroscopic bodies. As long as the chemical analysis of such bodies progressed, Gassendi pointed out, the clearer became that the ingredients of these same bodies went beyond the elements. The atoms of Lucretius were useful for another reason: in addition to their mechanical qualities (movement, size and gravity) they possessed particular shapes which, as we have seen, were the true causes of the peculiar molecular texture of bodies. It is interesting to note in passing that Gassendi introduced the term *moleculae* as the discriminatory element of the intrinsic complexity of matter, and that he does so while commenting a passage of the second book (135-141) of the *DRN*.[11] Within this framework the shapes of the atoms were the causes of heat, cold, light, sound etc. as well as of the chemical combinations of mixts. The importance of Gassendi for early modern chemistry has been already examined in many studies and this is not the occasion to insist further on this topic, rather I would like point out an aspect of both the *Animadversiones*[12] and the *Syntagma* which has been so far neglected: both works are editions of Lucretius' *DRN*. It is true that the *DRN* is not published in the original consequence but in his aim to revive its contents, Gassendi decided to scatter the verses according to a logic which followed the distinction made by Epicurus of philosophy, into canonic, physic and moral, taking physics and the most important part of the three.[13] Gassendi mixed his prose with descriptions of the experiments made by him and his contemporaries with commentaries of Lucretius' passages related to the topic he treated and Lucretius' atomism served him to provide a consistent theoretical basis to his chemistry.

Gassendi's works were highly successful and as early as 1654 William Charleton, a physician with a keen interest in Helmontian iatrochemistry, presented a synthesis of Gassendi's work into English.[14] But it was within the Fellows of the Royal Society of London that Gassendi and Lucretius found an attentive audience.

In this favourable context, it is not surprising that Robert Boyle adopted corpuscularism as one of the keys he used to interpret chemical combinations. He was also very positive towards Lucretius:

"By granting Epicurus his principles that the atoms or particles of bodies have an innate motions, and granting our supposition of the determinate motion and figure of the aerial particles, all the phenomena of rarefaction and condensation, of light, sound, heat etc., will naturally and necessarily follow."[15]

Lacking empirical ground, however, Lucretian atomism had to be mingled with Paracelsism and other sources with an approach more suited to the experimental outlook privileged by Boyle. On the other hand we should not underestimate the fact that due to his straightforward criticism against religion, his belief in the materiality and mortality of the soul, his cosmological thinking on infinite worlds, Lucretius was a highly controversial author whom, in order to avoid the accusation of atheism, could be cited only with cautious circumspection. This is certainly the reason why Boyle, in *The Sceptical Chymist* (1661) after having set his famous definition of the elements as "certain primitive and simple, perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the ingredients of which all those called perfectly mixt bodies are immediately compounded, and into which they are ultimately resolved"[16], tried to prove that his adherence to atomism was a stranger to Lucretius. On this matter he in fact declared:

"If I were fully to clear to you my apprehensions concerning this matter, I should perhaps be obliged to acquaint you with diver of the conjectures (for I muse yet call them no more) I have had concerning the principles of things purely corporeal: for though because I seem not satisfied with the vulgar doctrines, either of the peripatetick or Paracelsian schooles, many of those that know me […] have though me wedded to the Epicurean *Hypothesis*, (as others have mistaken me for an *Helmontian*) yet if you knew how little conversant I have been with *Epicurean* authors, and how great a part of *Lucretius* himself I never yet had the curiosity to read, you would perchance be of another mind."[17]

Naturally, Boyle's statement was guided by his firm aim at distinguishing his corpuscolarism from that of Thomas Hobbes which he regarded as dangerously heterodox and which was explicitly, though not entirely, based on Lucretius. In fact, other members of the Royal Society did not find Lucretius to be so dangerous and, as perceptibly noticed by Henry Guerlac, Isaac Newton was among the most enthusiastic supporter of Lucretian atomism, especially when its attention was focussed to explain the nature of the microscopic world. In the famous Query 31 of the *Opticks* devoted to the explanation of chemical reactions, Newton in fact wrote:

"it seems probable to me, that God in the Beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, of such Sizes and Figures, and with such other Properties, and in such Proportion to Space, as most conduced to the End for which he form'd them" [18] [i.e the composition of natural bodies].

The followers of Newton brought this idea further and applied it to iatrochemistry. This is the case of James Keill who, in order to explain the composition of blood set forth the following hypothesis:

"A few different sorts of particles variously combined, will produce great variety of fluids, some may have only one sort, some three, ore more … If we suppose only five different sorts of particles in the blood, and call them *a, b, c, d, e*, their several combinations, without varying the proportions, in which they are mixt will be these following:

ab: ac: ad: ae:
bc: bd: be: cd:
ce: de: abc: adc:
bdc: bde: bec: dec:
abcd: abc: acde: abd:
bcde: abcde:

But whether there are more or fewer in the blood, I shall not determine."[19]Arnold Thackray has seen in this explanation the first attempt to apply an algebraic method to chemistry and has not seen that Keill has used Lucretius' analogy between atoms and letters and that, exactly like the Latin poet, conceived no more than 5 difference atomic shapes, here represented with the initial letters abcde.

Following Boyle's application of the corpuscular hypothesis to chemistry, a typical reaction which was explained in Lucretian terms were those involving salts.

The French apothecary Nicolas Lemery, in is famous *Cours de Chymie* (Paris, 1675), conceived this specific chemical reactions in terms of particle shape and movement. While acids salts had a pointed shape which explained their sharp taste and their tendency to solidify by forming pointed crystals, alkalis were composed of a porous texture so shaped as to admit entry of the spike particles of acid.[20]

This result was to have crucial consequences.

During the early 1660s a pupil of Giovanni Alfonso Borelli and successor of Galileo in the chair of mathematical of the University of Pisa, Alessandro Marchetti, translated Lucretius into Italian and although the book was not printed until 1717,[21] manuscripts copies of the translation widely circulated and not only in Italy within scientific circles. Domenico Guglielimini was among those who was particularly influenced by Marchetti's translation and he was the one who introduced for the first time the term *molecole* in the Italian language.[22] Guglielimini took from Lucretius the idea that atom were constituted by *minimae partae* (minimal parts) which could be considered as geometrical figures and which were actually the cause of the different forms of atoms. These minimal parts, however, did not have an independent existence and the materiality was a quality which belonged exclusively to the atoms they belonged. It seemed therefore that the minimal part served Epicurus and Lucretius to build an atomic geometry which was alternative to that of Euclid (which as it is well know is based on the axiom that points have neither parts nor extensions) and at the same time to keep the physical materiality of the atom. Crystals observed with the microscope in salts seemed to confirm that elementary particles had specific geometrical forms! Following his observations with the microscope, Guglielmini developed the idea that the shape of the atoms constituting salts could be reduced to homogenous geometric forms deducted by the crystals configurations.

A salt reactions was visualized for the first time in the work *Conjectures physiques* by the Dutch natural philosopher Nicolas Hartsoeker.[23] He thus represented, for the first time in a scientific treatise, the shapes of the particles of an alkali as cylinders porous to the extremities. This particular shape made it natural to the pointed particles of acids, represented as nails, to fill the pores and to enter in combination with the alkali. Hartsoeker however went even further in his explanation of the reaction by showing how the round particles of water, represented as in Lucretius like small spheres, separated the alkali from the acids.

In 1768 d'Holbach promoted a French translation of Lucretius' *DRN*.[24] The author of the translation was La Grange, a materialistic philosopher tutor of d'Holbach sons, but the commentaries which accompanied the translation were the works of scientists, some of whom like the chemist Jean Darcet, were distinguished members of the Académie Royale des Sciences in Paris.

Against this background, it is not surprising that d'Holbach was one of the most important protagonist in the revival of Lucretius' doctrine of organic matter. In his *Système de la nature*, anonymously published in 1770, he summarised the contents of his work, and more generally of his philosophical doctrine, as follows:

"It will not then be inconsistent with observation, repugnant to reason, contrary to good sense, to acknowledge that matter is self-existent; that it acts by an energy peculiar to itself; that it will never be annihilated. Let us then say, that matter is eternal, that nature has been, is, and ever will be occupied with producing and destroying; with doing and undoing, with combining and separating; in short, with following a system of laws resulting from its necessary existence. For every thing that she doth, she need only to combine the elements of matter; these, essentially diverse, necessarily either attract or repel each other; come into collision, from whence results either their union or dissolution."[25]

As emphasised by this passage, d'Holbach attributed to matter an inner energy, to nature the necessity of laws regulating occurrence of natural phenomena, and to sensuous experience the possibility of knowing and manipulating them by following the paths indicated by nature herself. D'Holbach had been the translator of Stahl's chemistry into French and his idea on matter heavily relied upon the conviction that atoms had an inner force which enabled them a self organization. His doctrine, shared by Rouelle, Roux and Darcet, was mixture of materialistic and vitalistic concept which on the one hand enhanced the epistemological value of qualitative chemistry and on the other undermined mathematical authority.

From an entirely different perspective Lavoisier developed a corpuscular view of matter which also relied on the reading of Lucretius. While Lavoisier shared d'Holbach's views that chemistry could not be reduced to mathematics and that the appreciation of the individual qualities of the ingredients of a reaction was its distinctive feature, he thought that quantification had a central role in the exact identification of these same ingredients. To this aim, between 1766 and 1767, he proposed to measure the quantity of salts dissolved in water by determining their specific gravities and by preparing comparative tables of the results. What he expected from these results was to gain different quantitative numerical data for each and every salt he had analysed. Lucretius also thought that each solid body had a different specific gravity and that this was due to the fact that atoms themselves had different specific weight. Lavoisier owned two copies of the Latin poem, one in Latin and the other in French in the d'Holbach edition.[26] True, Lucretius was never cited in Lavoisier's works. However, there are several instances in his work of analytical chemistry which clearly show a close reading of the Latin poem. Space limitation does not permit to go through them now. Here it suffices to mention the most evident, and perhaps most important, of them. In 1789 Antoine Laurent Lavoisier published a *Traité élémentaire de chimie* a work which, according to his contemporaries introduced the quantitative method of analysis of reaction as the sole viable investigative path for chemistry. In the central part of the *Traité* the French chemist established that

"in all the operations of art and nature, nothing is created; an equal quantity of matter exists both before and after the experiment; the quality of the elements remains perfectly the same; and nothing takes place beyond changes and modifications of these elements. Upon this principles the whole art of performing chemical experiments depends: we must always suppose an exact equality between the elements of the body examined and those of the products of its analysis."[27]

The identity of this principle, eventually regarded as one of the most important laws of chemistry, with Lucretius's doctrine of conservation of matter is remarkable. The Latin poet in fact stated in the first book of his poem that "nothing is ever produced from nothing" and that "no single thing returns to nothing, but all by disruption return to the elements of matter". (*DRN*, I, v. 150 e 248-50).

After Lavoisier chemical atomism gained momentum and with the works by Berthollet, Dalton, Berzelius and Avogadro a new story began which finally left Lucretius behind and in which no traces of the classical atomism were left. This shift became possible because the systematisation Lavoisier gave to chemistry made it useless to resort to the history of atomism and gave a modern basis in which chemistry could progress with its own autonomous theoretical means.

Notes

[1] All the citations from Lucretius' *De rerum natura* (hereafter abbreviated as *DRN*) have been taken, with a few modifications, from volume 1 of *Titi Lucreti Cari De rerum natura libri sex*. Edited with Prolegomena, Critical Apparatus, Translation, and Commentary by Cyril Bailey (Oxford: The Clarendon Press, 1947), 3 vols. A different version of this paper has been published with the title "Lucrezio e la chimica", *Automata*, 2 (2007), pp. 41-57

[2] *The Works of Aristotle translated into English under the editorship of W. D. Ross* (Oxford: At the Clarendon Press, 1947) vol. 2.

[3] William R. Newman, *Atoms and Alchemy: Chymistry and the experimental Origins of the Scientific Revolution* (Chicago: The University of Chicago press, 2006).
[4] *In Carum Lucretium poetam commentarij a Ioanne Baptista Pio editi, codice Lucretiano diligenter emendato, nodis omnibus et difficultatibus apertis, obiter ex diuersis auctoribus tum Grecis tum Latinis multa leges enucleata, que superior etas aut tacuit aut ignorauit* (Bononiae : typis excussoriis editum in ergasterio Hieronymi Baptistae de Benedictis Platonici Bononiensis, 1511 kal. Maii).
[5] *DRN*, I, 149-150.
[6] *DRN*, I, 215-216.
[7] Francis Bacon, *The Works … Collected and Edited by James Spedding, Robert Leslie Ellis and Douglas Denon Heath*, vol. 4 (London: Longman & Co., 1858), p. 197. The Latin version of the same text is quoted in the first volume of the same edition on p. 311.
[8]Francis Bacon, *The Works , Op. cit.,* vol. 4, p. 197
[9] *An essay on the first book of T. Lucretius Carus De rerum natura interpreted and made English verse by J. Evelyn* (London: printed for Gabriel Bedle and Thomas Collins, 1656).
[10] Olivier René Bloch, *La philosophie de Gassendi. Nominalisme, Matérialisme et Métaphysique* (La Haye : Nijhoff, 1971), p. 241.
[11] Pierre Gassendi, *Syntagma Philosophicum* in Id., *Opera Omnia*, (Lugduni: sumptibus Laurentii Anisson & Ioan. Bapt. Devenet, 1658), 6 vols. on vol. 1, p. 282b.
[12] Pierre Gassendi, *Animadversiones in decimvm librvm Diogenis Laertii, qvi est de vita, moribus, placitisque Epicvri: continent autem Placita, quas ille treis statuit philosophiae parteis: I, Canonicam nempe, habitam Dialecticae loco; II, Physicam, ac imprimis nobilem illius partem meteorologiam; III, Ethicam, cuius gratiâ ille excoluit caeteras* (Lvgdvni: apud Gvillelmvm Barbier, 1649), 3 vols.
[13] In a letter addressed to Gabriel Naudé, by referring to his own method of using Lucretius, Gassendi wrote: "Sed erit forte, quod uterque in eodem campo decurramus, cum ille Lucretium ex serie contextus interpretatus sit, ipse methodo paullo immutata Lucretium producturus sim, ad explicationem, confirmationemque placitorum Epicureorum hinc *totus quidem Lucretius in opellam mean transferetur*; sed carminum ordo mihi perturbatus, planeque varius futurus est» (my Italics). Gassendi, *Opera,* vol. 6, pp. 49-50.
[14] Walter Charleton, *Physiologia Epicuro-Gassendo-Charltoniana: or a fabrick of science natural upon the hypotesis of atoms with indexes and a new introduction by Robert Hugh Kargon,* Repr. from the London ed. 1654 (New York: Johnson reprint corporation, 1966).
[15]Robert Boyle, *Works* (London 1772), vol. 1, p.180.
[16] *The Works of Robert Boyle. Edited by Michael Hunter and Edward B. Davis* (London: Pickering & Chatto, 1999), vol. 2, p. 345.
[17] *The Works of Robert Boyle. Edited by Michael Hunter and Edward B. Davis* (London: Pickering & Chatto, 1999), vol. 2, p. 354.
[18]Isaac Newton, *Opticks*, Ed. by I. B. Cohen, New York, Dover Publications, 1979, p. 400.
[19] James Keill, *An Account of animal secretion, the quantity of blood in the human body, and muscular motion* (London: 1708), pp. 61-61, quoted in Arnold Thackray, *Atoms and Powers. An Essay on Newtonian Matter-Theory and the Development of Chemistry* (Cambridge Mass.: Harvard University Press, 1970) p. 70.
[20] "Comme one ne peut pas mieux expliquer la nature d'une chose aussi cachée que l'est celle d'un sel, qu'en attribuant aux parties qui le composent des figures qui répondent à tous les effets qu'il produit, je dirai que l'acidité d'une liqueur consiste dans des particules de sel pointues, lesquelles

sont en agitation ; & je ne crois pas qu'on me conteste que l'acide n'ait des pointes, puisque toutes les expériences le montrent." Lémery, *Cours de Chymie* (Paris: d'Houry, 1757), p.17.

[21] *Di Tito Lucrezio Caro Della natura delle cose libri sei. Tradotti da Alessandro Marchetti lettore di filosofia e mattematiche nell'universita di Pisa et accademico della Crusca* (London: John Pickard, 1717). On this and all the editions of Lucretius published with the contribution of natural scientists see my "Gli scienziati e le editioni del *De rerum natura*" in, Marco Beretta and Franceco Citti (eds.), *Lucrezio, la natura e la scienza* (Firenze: Leo S. Olschki) forthcoming.

[22] Domenico Guglielmini, *Riflessioni filosofiche dedotte dalle figure de' sali dal dottore Domenico Guglielmini espresse in vn discorso recitato nell'Accademia filosofica esperimentale di monsig. arcidiacono Marsigli la sera delli 21. marzo 1688* (Bologna : per gli eredi d'Antonio Pisarri, 1688) Chapter 79.

[23] Nicolas Hartsoeker, *Conjectures physiques* (Amsterdam, 1706).

[24] *Lucrece. Traducion nouvelle avec des notes* (Paris: Bleuet, 1768) 2 vols.

[25] "Reconnoisons donc que la matière existe par elle-même, qu'elle agit par sa propre énergie et qu'elle ne s'anéantira jamais. Disons que la matière est éternelle, et que la nature a été, est et sera toujours occupée à produire, à détruire, à faire, et à défaire, à suivre des loix résultantes de son existance nécessaire. Pour tout ce qu'elle fait elle n'a besoin que de combiner des élémens et des matières essentiellement diverses qui s'attirent et se repoussent, se choquent ou s'unissent, s'éloignent ou se rapprochent, se tiennent assemblées ou se séparent. C'est ainsi qu'elle fait éclore des plantes, des animaux, des hommes ; des êtres organisés, sensibles et pensants, ainsi que des êtres dépourvus de sentiment et de pensée. Tous ces êtres agissent pendant le tems de leur durée respective suivant des loix invariables, déterminées par leurs propriétés, leurs configurations, leurs masses, leurs poids, etc. » d'Holbach, *Système de la nature* (1770) (Paris: Fayard, 1990), t. 2, p. 171.

[26] *Titi Lvcretii Cari De rervm natvra libri sex, ad postremam Oberti Gifanii Ic. emendationem accuratissimè restituti. Quae praetereà in hoc opere sint praestita, pagina post dedicationem indicabit* (Lvgdvni Batavorvm: ex officina Plantiniana, apud Franciscum Raphelengium, 1595); *Lucrèce, traduction nouvelle, avec des notes, par M. L* G*** (Paris: Bleuet, 1768) 2 voll.

[27] "On voit que, pour arriver à la solution de ces deux questions, il fallait d'abord bien connaître l'analyse et la nature du corps susceptible de fermenter, et les produits de la fermentation ; car rien ne se crée, ni dans les opérations de l'art, ni dans celles de la nature, et l'on peut poser en principe que, dans toute opération, il y a une égale quantité de matière avant et après l'opération; que la qualité et la quantité des principes est la même, et qu'il n'y a que des changements, des modifications.

C'est sur ce principe qu'est fondé tout l'art de faire des expériences en chimie: on est obligé de supposer dans toutes une véritable égalité ou équation entre les principes du corps qu'on examine et ceux qu'on en retire par l'analyse." Lavoisier, *Traité élémentaire de chimie* (Paris : Cuchet, 1789), vol. 1, pp. 140-141.