Boyle, Spinoza and Glauber: On the *Philosophical Redintegration* of Saltpeter

A Reply to Antonio Clericuzio

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Abstract:

Traditionally, the so-called 'redintegration experiment' is at the center of the comments on the supposed Boyle/Spinoza correspondence. A. Clericuzio argued (refuting the interpretation by R.A. & M.B. Hall) in his influential publications that, in *De nitro*, Boyle accounted for the 'redintegration' of saltpeter on the grounds of the chemical properties of corpuscles and did not make any attempt to deduce them from the mechanical principles.

By contrast, this paper claims that with his *De nitro* Boyle wanted to illustrate and promote precisely his new Corpuscular or Mechanical Philosophy, and that he did significant attempts to explain the phenomena in terms of mechanical qualities. Boyle had borrowed the 'redintegration experiment' from R. Glauber and used it as a tool to prove that his philosophy was the right alternative for the Peripatetic and Paracelsian theory of qualities of bodies.

Consequently, Clericuzio's characterization of the Boyle/Spinoza controversy as a discussion between a strict mechanical philosopher and a chemist is problematic and should be revised.

Key-words:

Spinoza, Boyle, Glauber, Corpuscular Philosophy, Mechanical Philosophy, saltpeter.

Introduction[2]

In October 1661, Henry Oldenburg (1618-1677) sent a Latin translation[3] of "one of the most seminal" writings of Robert Boyle's entire career to Spinoza (1632-1677). (Hunter 2009, p. 112) This was the start of an indirect correspondence between Boyle (1627-1691) and Spinoza. Central in Spinoza's critical comments on Boyle's *Certain Physiological Essays* (1661) and its interpretations in secondary literature is the so-called '*redintegration'* experiment by which saltpeter (or niter) is decomposed and recomposed or 'redintegrated'.

In two influential publications, published in 1990 and 2000, Antonio Clericuzio presented his views on the supposed Boyle/Spinoza controversy, arguing that the contrast between the Dutch philosopher

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[2] In this article I use the following abbreviations: WOB = Works of Robert Boyle. Edited by Michael Hunter and Edward B. Davis and CWS = The Collected Works of Spinoza, Edited and translated by Edwin Curley.

[3] The first published Latin translation was by Gilbert Havers. This *quarto* edition was registered by the publisher, Henry Herringman, on 13 June 1661. However, in the late 1650s a Latin translation had been prepared by Henry Strubbe. The first published version of the English text had been registered by the same publisher under the title "*A Proemiall Essay*" on 29 October 1660 and on 28 April 1661 under the title "*Certain Physiological Essays*". (Hunter, WOB, vol. II, xiii-XV).

and the author of *The Sceptical Chymist* (1661) is not about an opposition between the rationalist versus empirical philosophy - as A.R. and M.B. Hall (1964) had argued before him - but on the role of mechanical explanations in chemistry. According the Italian historian, Spinoza's "corpuscular philosophy" is "strictly mechanical and reductionistic"; whereas Boyle "accounted for the 'redintegration' on the grounds of the chemical properties of corpuscles and did not make any attempt to deduce them from the mechanical principles." (Clericuzio 2000, p.139 and 141)

This paper contests this view. Firstly, it demonstrates that, with his *De nitro*, Boyle wanted to illustrate and promote in the first place the plausibility of a new philosophy, the Corpuscular Philosophy or Mechanical Philosophy, thereby attempting to unite atomists and Cartesians in one common prestigious project. Moreover, this paper claims that the *redintegration* experiment as such - which was indeed at the center of Spinoza's comments - was not essential from Boyle's point of view. The redintegration of saltpeter was in fact only a tool to illustrate the plausibility of his new philosophy which he introduced in *Certain Physiological Essays* and would promote for the rest of his life in other subsequent works such as *The origine of formes and qualities, (according to the corpuscular philosophy)*[4] (1666-67), *About the Excellency and Grounds of the Mechanical Hypothesis* (1674) and *Mechanical Origin of Qualities* (1675).

Additionally, this paper argues that Johan Rudolf Glauber (1604-1670) – who is completely absent in Clericuzio's interpretation - needs to be included in the discussion of the context of the Spinoza/Boyle correspondence. This paper highlights that the *redintegration* was not executed for the first time by Boyle. In fact, this was an experiment of Glauber whose work was known to Boyle. Consequently, the Anglo-Irish natural philosopher might have borrowed Glauber's experiment to show the potential of his prestigious project which had to replace the peripatetic doctrine of qualities and the one of the "chymists" based on Paracelsus's ideas. Moreover, this paper argues that Glauber's work was not only known to Boyle but probably also to Spinoza whose birthplace was only a stone's throw from the well-known lab of the German alchemist/chemist.

In the third section, this paper compares Boyle, Spinoza's and Glauber's interpretation of the *redintegratio* experiment. Finally, it is shown - based on Boyle's definition of Mechanical Philosophy and Spinoza's interest in alchemy - that it is, for several reasons, very problematic to categorize Spinoza as a radical philosopher whose corpuscular philosophy was strictly mechanical and reductionistic, as Clericuzio[5] does repeatedly.

[4] The full title of this work is: "The origine of formes and qualities, (according to the corpuscular philosophy) illustrated by considerations and experiments (written formerly by way of notes upon an essay about nitre) by ... Robert Boyle ...".

[5] See for instance: Clericuzio, 2000, p. 135 and 139.

Boyle and Spinoza on a different wavelength: Robert Boyle's aim

a. The context of the Boyle/Spinoza correspondence

Back in London, after his visit to Spinoza in Rijnsburg during the summer of 1661, Henry Oldenburg wrote to Spinoza to invite him to maintain contact. In this first letter already, the German immigrant mentioned a newly published book by an English nobleman. And a few months later, he sent the Latin translation of Robert Boyle's *Certain Physiological Essays*[6], entitled *Tentamina quaedam physiologica diversis temporibus et occasionibus conscripta,* to the Dutch philosopher asking for his critical comments. The German immigrant and friend of Robert Boyle, clarified that he was especially interested in his views on the experiments which were explained in the book. Spinoza accepted Oldenburg's invitation and gave his critical comments in his longest existing letter, *Letter 6*, dated April 1662. This letter is part of the so-called Boyle/Spinoza correspondence which consists of two letters of Spinoza [*Letter 6* (1661) and *Letter 13* (1663)] and two of Oldenburg/Boyle [*Letter 11* (1663) and *Letter 16* (1663)]. This correspondence between Spinoza and Boyle was however never direct but always indirect via Henry Oldenburg[7]. In his first letter of the Boyle/Spinoza controversy, Spinoza gave much attention to the so-called redintegration experiment with saltpeter. Boyle had explained this experiment in a treatise entitled *De nitro* which he had included as the fourth of the five treatises of his *Certain Physiological Essays*, which has the following structure:

1. A Proemial Essay
2. Two Essays concerning the Unsuccessfulness of Experiments, etc.
3. Some specimens of an Attempt to make Chymical Experiments useful to illustrate the notions of the Corpuscular Philosophy.
    a. A physical-chymical Essay containing An Experiment with considerations touching the different Parts and Redintegration of SALT-PETRE.
    b. The history of Fluidity and Firmness.

b. Boyle and Spinoza on a different wavelength

In his letter of 3 April 1663, Oldenburg thanks Spinoza for his critical comments. However, before he deals with the matter, he advises Spinoza – on behalf of Robert Boyle – to have the real purpose of the

[6] The second edition of Boyle's *Certain Physiological Essays* is included in: WOB, II, p. 3-203.
[7] The correspondence between Baruch Spinoza and Henry Oldenburg is composed of 17 letters from Oldenburg to Spinoza and 10 from Spinoza to Oldenburg. These letters are written between 1661 and 1676. The 'Spinoza-Boyle' correspondence forms a part of this larger whole.

"Chemical-Physical Treatise" in mind[8]. In the second paragraph of his second and final letter of the Boyle/Spinoza correspondence, dated 4 August 1663 (*Letter 16*), Oldenburg asks Spinoza once again "to understand the true goal he [Boyle] had set himself in that Work" and insists that Spinoza read the preface[9] of *Some specimen of an Attempt* wherein he had explained extensively the true aim of his work:

> He [Robert Boyle] asks you to consult the Preface to his Experiments on Niter, to understand the true goal he had set himself in that Work: to show that the teachings of a more solid Philosophy, which is now appearing again, can be illustrated by clear experiments, and that these [experiments] can be explained very well without the forms, qualities and futile elements of the Schools. But he did not at all take it on himself to teach the nature of Niter nor even to reject what anyone can maintain about the homogeneity of matter and about the differences of bodies arising only from motion, shape, etc. He says he had only wished to show that the various textures of bodies produce their various differences, that from these proceed quite different effects, and that so long as the resolution to prime matter has not been accomplished, Philosophers and others rightly infer some heterogeneity from this. I should not think that there is any fundamental difference between you and Mr. Boyle here[10].

In sum, Boyle repeatedly makes clear to Spinoza - via Oldenburg - that he was missing the point completely. What was at stake for Boyle was not the examination of the nature of Saltpeter nor the analyses of the redintegration experiment as such, but the promotion of a new philosophy: The Corpuscular Philosophy, a term which he preferred to 'Mechanical Philosophy'.

The supposed controversy between Boyle and Spinoza has been interpreted by several scholars such as Henri Daudin as an opposition between the philosopher/metaphysician ["*le philosophe métaphysicien"*] Spinoza and the experimenter/ technician ["*l'expérimentateur, le technician"*] Robert Boyle. (Daudin 1949) But, surprisingly, the early scientist Robert Boyle himself insists here that the philosopher Spinoza be less scientific and technical and much more philosophical in his interpretation and comments.

c. Boyle's aim

As shown in the paragraph above, Boyle wanted Spinoza to have the aim of his work in mind. But what was the aim of Robert Boyle to which Oldenburg referred repeatedly? The answer to this

[8] CWS, I, 197.
[9] WOB, 2, 85-91.
[10] CWS, I, 216-218.

question is found in the preface that precedes *De nitro* in *Certain Physiological Essays.* In this polemic text, he reveals that he wants to replace the Peripatetic theory of qualities of bodies and theories based on the idea of Paracelsus (1493/94-1541) with his own new natural philosophy which he introduced here for the first time in his career[11].

Not only in this preface but also in other texts, written much later, he argues that his mechanical hypothesis provides a simpler and more compelling explanation for more natural phenomena (Hunter 2009, 116). Furthermore, he claimed that this could be illustrated by clear experiments which could be explained without the unintelligible substantial forms, real qualities and "futile elements of the Schools".

Interestingly, in the same preface he gives a precise definition of his new philosophy, introducing the term 'Mechanical Philosophy' into the English language which at the time the term sounded still very odd in all European languages and in Latin:

> That both parties agree in deducing all the Phaenomena of Nature from Matter and Local motion; I esteem'd that notwithstanding those things wherein the Atomists and the Cartesians differ'd, they might be thought to agree in the main, and their Hypotheses might by a Person of a reconciling Disposition be look'd on as, upon the matter, one Philosophy. Which because it explicates things by Corpuscles, or minute Bodies, may (not very unfitly) be call'd Corpuscular; though I sometimes stile it the Phoenician Philosophy, because some ancient Writers inform us, that not only before Epicurus and Democritus, but ev'n before Leucippus taught in Greece, a Phoenician Naturalist [Moschus] was wont to give an account of the Phaenomena of Nature by the Motion and other Affections of the minute Particles of Matter. Which because they are obvious and very powerfull in mechanical Engines, I sometimes also term it the Mechanical Hypothesis or Philosophy[12].

In this definition we can distinguish seven key elements[13]. First of all, the study-object of the mechanical philosophy is nature and all natural phenomena (*Element 1*). Indeed, the redintegration that was an experiment with salt-peter was in fact an instrument to show something which is true for all bodies. As Boyle reveals already in the first section of his *De nitro*, salt-peter was in his view a paradigmatic example for all bodies. In this section, he writes that "Salt -peter is sold in the shops" and "it is to be found in so great a number of Compound Bodies, Vegetable, Animal, and even Mineral, that it seems to us to be only one of the of the most Catholick of Salts, but so considerable an Ingredient of many sublunary concretes, that we may justly suppose it may well deserve our serious enquires, since the knowledge of it may be very conductive to the discovery of the Nature of several other bodies, and to the improvement of divers parts of Natural Philosophy."[14] Obviously this phrase echoes the views on salt-peter of the alchemist R. Glauber, who had already written extensively on salt-peter, to which we will come back later.

[11] WOB, 2, 87.
[12] WOB, 2, 87.
[13] For a more detailed discussion of this definition see, for instance: Buyse, 2010 and Buyse, 2013.
[14] WOB, 2, 93.

Secondly, there are only "two grand and most Catholic principles" as Boyle put it: matter and motion, or more precisely: passive matter and local motion. (*Element 2*). Therefore, Boyle argued that his natural philosophy was much more economical than the Peripatetic hypotheses which had 4 elements and the Paracelsian one which had three. Thirdly, the new philosophy explains the natural phenomena in terms of mechanical affections[15] such as motion, size and shape. (*Element 3*) It is important, however, to notice that the definition does not only create a primary/secondary distinction between the mechanical qualities and the secondary qualities[16] but also between the macro and the microworld (*Element 4*) since according to this definition the phenomena do not have to be explained in terms of the mechanical properties of the bodies but in terms of the mechanical properties of the corpuscles that compose these bodies (*Element 5*). Obviously, Boyle was inspired here by the atomism of Epicurus, Democritus and Leucippus as he indicates in his definition. Additionally, Boyle adds the analogy of the mechanical machine to clarify his views[17]. *(Element 6)* Oldenburg had already written in his *Letter* 3 (27 September 1661) to Spinoza that in his "Philosophical Group" they were much "occupied with putting together a History of the Mechanical Arts" for they regarded "it as settled that the forms and qualities of things can best be explained on Mechanical Principles, that all nature's effects are produced by motion, shape, and texture, and their various combinations, …"[18]

Finally, the epistemological status of the Corpuscular or Mechanical Philosophy is that of a hypothesis that had to be validated experimentally. (*Element 7*) As we will see further in this article, this last element will constitute a significant difference between the views of Boyle and those of Spinoza. Boyle did choose the word 'hypothesis' very carefully since he wrote in the same period a treatise on "*The Requisites of a Good Hypothesis*" of which only fragments survive. In this work, he argues that the first requisite of a good hypothesis it that it is intelligible.

In sum, as the title "Some specimens of an Attempt to make Chymical Experiments useful to illustrate the notions of the Corpuscular Philosophy" of the third of his *Certain Physiological Essays* had suggested, Boyle wanted with the redintegration experiment to illustrate the plausibility of his corpuscular philosophy. That *De nitro* should really be understood in the context of Boyle's new philosophy of bodies is also confirmed by what he would write in a work which he started to write in the same period but would only publish in 1686 entitled *A Free Enquiry*. In this metaphysical work he criticizes the scholastics who call the substantial forms and real qualities '*semi-substantia'.* When reflecting, he speaks about *De nitro* as 'A Chemico-Physical Essay about Salt-petre', against the

[15] Boyle calls the primary properties of corpuscles in his "*Of the Imperfecion of the Chymist's Doctrine of Qualities*" 'corpuscularian Principles'. See WOB, 8, 401.
[16] See also section XII of *De nitro*: WOB, 2, 98.
[17] See also WOB, 8, 399.
[18] CWS, I, 169-170.

pretended origin and inexplicable nature of the imaginary substantial forms of the Peripatetics (Boyle 1996, p.61).

Clericuzio cannot think of a reason why Boyle should have appealed to the redintegration process in defence of his Mechanical Philosophy. However, there is an obvious reason. Indeed, as Michael Hunter put it (Hunter 2009, p. 116), with his experiment Boyle thought he could show that all substances in general, and saltpeter in particular, are composed of distinct parts which differ from the original substance, since they could "taken apart and put back together mechanically" as a machine, e.g. a pendulum clock. After all, that's why the Anglo-Irish natural philosopher uses the term 'Mechanical Philosophy' as a synonym for 'Corpuscular Philosophy' referring to the Greek word for 'instrument' or 'machine'. Moreover, as his definition prescribed, Boyle could explain the phenomenon in a multi-realizable way so to speak; without assuming different basic stuffs. The phenomenon could be explained as a decomposition and synthesis or in other words a rearrangement of parts composed of the same basic inert material. Like with clocks the differences between bodies was conceived very fundamentally as a difference in motion, size, form and arrangement of parts of the bodies.

One of the basic elements of this new philosophy was the doctrine of qualities of bodies (*element 3, 4 and 5*). Clericuzio argues that "It is noticeable that in *Certain Physiological Essays* Boyle does not make any attempt to deduce these sensible qualities [tastes and colours] from the shape or size of the corpuscles of the substances in question." (Clericuzio, 1990, 575). However, this is precisely what Boyle intends ("I shall …") to do in Section XII, just after his explanation of the experiment itself. Obviously, Boyle wants to demonstrate in the next sections that all sensible phenomena that go together with the experiment can be explained in terms of primary qualities of the corpuscles:

> The reflections which may be made on this Experiment are more than I have either the skill or leisure to prosecute, and therefore I shall content my self to present you very succinctly with a few of those that do the most readily occur to my present thoughts.
> And first, this Experiment seems to afford us an instance by which we may discern that Motion, Figure, and Disposition of parts, and such like primary and mechanical Affections (if I may call them) of Matter, may suffice to produce those more secondary affections of Bodies which are wont to be called Sensible Qualities[19].

It is noticeable that he introduces in this citation the primary/secondary terminology into the English language for the first time, after he had introduced "Mechanical Philosophy" in his preface (a terminology which his student Locke would take over and integrate systematically in his own philosophy). Interestingly, Boyle's efforts to illustrate his theory of qualities are clearly reflected in the structure of his text, which attributes a separated section for each of the five senses starting with "The Tangible qualities" in section XIII:

[19] WOB, 2, 98.

And to begin with the Tangible Qualities, as Heat and Cold; it is commonly held, that Salt-Petre is in operation a Cold Body, if not one of the coldest in the world

[…]; and did in our Experiment produce such an heat, that I could scarcely endure to hold in my hand the Vial, wherein much lesse than an ounce of each was mix'd, though but leisurely and almost by drops: as if Heat were nothing but a various and nimble motion of the minute particles of Bodies. For in our Experiment, as long as that confus'd agitation lasted, so long the heat endur'd, and with that agitation it / encreas'd and abated; and at length when the motion ceas'd, the heat also vanish'd[20].

In Section XIV, Boyle tries to explain sound in mechanical terms as the effect of "swift and irregular motions of the particles of the Liquors":

This sound seem'd to proceed from the nimble and smart percussions of the ambient air, made by the swift and irregular motions of the particles of the Liquors: And such a kind of sound, but much lowder, was produc'd by the impetuous eruptions of the halituous flames of the Salt-Petre upon the casting of a live coal upon it.

And in section XV he continues arguing that a modification of the disposition of the parts produces new color effects:

[…] That disposition of parts, whereby the light reflected to the eye, was so modify'd as to produce that colour being now alter'd. […][21]

And in Section XVI, Boyle clarifies that the agitation of corpuscles leads to a very strong and offensive smell.

[…] Upon the mixture of these two Liquors there also obtrudes it self upon the Sense a very strong and offensive smell, proceeding from the Spirit of Petre; […]
[…] But though the Nitrous Spirit have a very strong and unwelcome odour of it self, yet it is made much more offensive by being pour'd on its own fix'd Salt; for upon their conflict, the matter, being vehemently agitated, doth more copiously emit such stinking exhalations than before, and sendeth forth fumes manifestly discernable as well to the Eye as Nostrils. […][22]

Finally, in his explanation of taste of bodies, the primary affection of "forme" ("more perfect", "not fully incorporated", …) is decisive. Furthermore, Boyle applies mechanical metaphors such as "a taste more sharp and perforating" to express how the taste is experienced:

The tastes of these bodies are as differing as any of their other qualities: […] And though we must not conceal from you, that in our trial the redintegrated Salt-Petre had upon its first impression upon the tongue a taste more sharp and perforating (if I may so speak) than ordinary Nitre; yet that pungency may not improbably be supposed to have proceeded from Acid particles of the Spirit that were not yet duly incorporated with, but onely loosely adherent to; the more perfectly Nitrous parts, which afterwards discover'd it self upon the tongue. […][23]

In sum, contrary to Clericuzio's claims, Boyle does try to explain qualities in mechanical terms. It makes sense to question whether he succeeds doing so convincingly, but it cannot be denied, that he makes a significant attempt.

[20] WOB, 2, 99.
[21] WOB, 2, 100.
[22] WOB, 2, 101.
[23] WOB, 2, 101.

d. Spinoza's reply to Boyle's aim

Spinoza pretends that he could hardly believe that Boyle had "no other object in his Treatise on Niter than to show the weak foundations of that childish and frivolous doctrine of Substantial Forms and Qualities."[24] Therefore, he clarifies, he had discussed in his first letter the nature of saltpeter and Boyle's methodology. In his view, the redintegration experiment was for two reasons - as a proof of the mechanical doctrine of qualities – completely redundant. First of all, because Bacon (1561-1626) and later Descartes (1596-1650) had already adequately demonstrated that "all tangible qualities depend only on motion, shape, and remaining mechanical affections"[25]. Secondly, he had a problem with the fact that Boyle presented his theory of qualities of bodies as hypotheses that had to be validated by scientific experiment. In his view, these kinds of experiments didn't prove anything. The reconstitution of Nitre was only an excellent experiment, he clarifies, "for investigating the very nature of nature when we first know the Mechanical Principles of Philosophy and that all variations of bodies happen according to the laws of Mechanics."[26]

By contrast, A. Clericuzio argued that Spinoza had no problems with Boyle's experimental methodology. Moreover, the Italian historian argues that Spinoza even proposed additional experiments (Clericuzio 1990, p. 576-577). However, as Pierre Macherey (Macherey 1995, p.746-756) had already pointed out in an extensive paper (which is not mentioned by the Italian historian) it is important to acknowledge that Spinoza made a strict distinction between scientific experimentation [*experimentum*] and ordinary experience [*experientia vaga*][27]. According to the Dutch philosopher, the problem is not that experiments, such as the redintegration experiment, are scientific. On the contrary, Spinoza is of the opinion that they are they are not scientific enough. He remarks that Boyle should have weighed the substances and have applied mathematical reasoning, anticipating Lavoisier (1743-1794)[28]. Moreover, per definition, in scientific experiments you try to control the circumstances which is in Spinoza's view is an illusion since this controlling is too much based on sensible knowledge which is according to his theory of knowledge[29] necessarily inadequate and necessarily leads to new inadequate ideas. Instead, according to Spinoza, the starting point for all adequate knowledge in general and knowledge of the mechanical doctrine of qualities in particular is ordinary experience [*experientia vaga*]. He illustrates this very clearly with numerous examples in his

[24] CWS, I, 208.
[25] Cf. CWS, I, 178.
[26] CWS, I, 210.
[27] This distinction that Spinoza makes here goes back to Bacon. Cf. *The Emendation of the Intellect*, 19 and *Novum organum*, I, 82. For the relation between Bacon and Spinoza concerning the *experimentum*/*experientia vaga* distinction see also Gabbey, 1997, 172-180.
[28] Cf. CWS, I, 174.
[29] For Spinoza's theory of knowledge, see: the second part of his *Ethics*.

letter to Boyle. Likewise, the "three quite easy experiments"[30] that he proposes are part of ordinary experience rather than of scientific experimentation: "I deny that that these things follow more clearly and evidently from the experiment than from readily available experiments […]"[31].

Spinoza's reply to Boyle's remarks concerning the aim of his work are trustworthy given the fact that he had written already in one of his early writings (more precisely in Chapter VI of the second part of the *Cogitata metaphysica*) that he had at this moment already "shown that there is nothing in matter but mechanical constructions and operations."[32] Furthermore, he writes very similar things in his later work and correspondence which illustrates that his views on this subject were very stable throughout his life. For instance, in the appendix of the first part of the *Ethics*[33], he writes that sensible qualities do not represent the bodies as they are in themselves, just as he had done this in his *Letter 6* to Boyle, defending the idea that sensible qualities are affections of the body. In the *Physical Interlude* of the second part of the *Ethics*, he defines a body as a whole of parts which participate in the same relation of motion and rest. And in his *Letter 56* (1674) to Hugo Boxel he severely criticizes severely a whole philosophical tradition based on the ideas of Plato and Aristotle which explained natural phenomena based on "occult qualities, intentional species, substantial forms, and a thousand other trifles contrived ghost and spirits, […]"[34]showing instead much sympathy for the ideas of "Epicurus, Democritus, or any of the Atomists, or defender of invisible particles" as Boyle had done in his definition of Mechanical philosophy.

The redintegration experiment

a. Glauber's *versus* Boyle's version

Boyle describes in section XXVIII of his *De nitro* (which came out in English in March 1661 and in Latin in *quarto* in June of the same year) the redintegration experiment as follows:

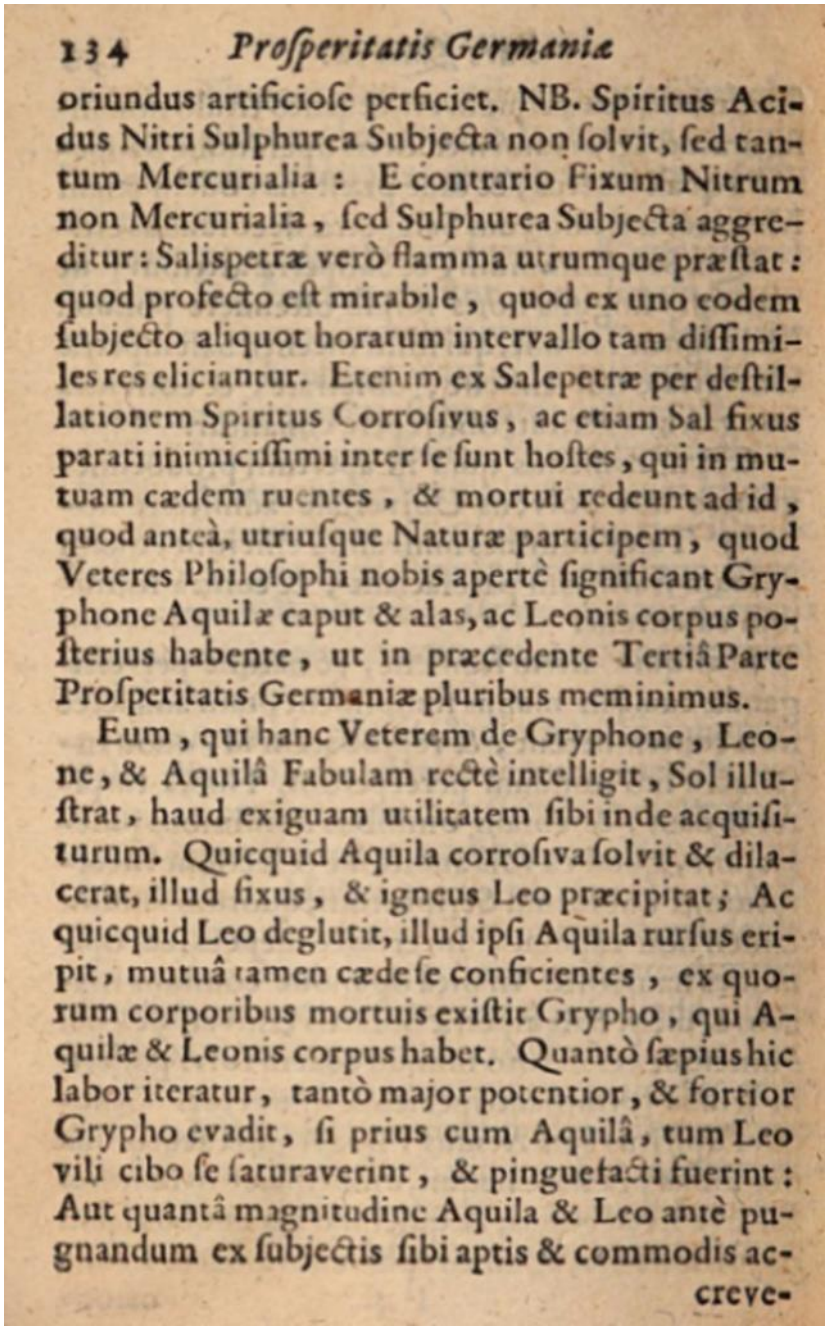
> when Salt-Petre is distill'd, the volatile liquor and fix'd Salt into which it is reduc'd by the fire, are endowed with properties exceeding different both from each other, and from those of the undissipated Concrete: for the Spirit of Nitre is (as we formerly have observ'd) a kind of *Acetum Minerale*, and possesses the Common qualities to be met with in acid spirits as such; whereas the fix'd Nitre is of an Alkalizate nature, and participates the qualities belonging generally to lixiviate Salts; and Salt-petre it self is a peculiar sort of Salt, discriminated by distinct properties both from those Salts that are eminently acid […] and from those that are properly Alkalizate […] And whereas Salt-Petre it self is partly fix'd, and partly volatile, the acid Ingredients of it are altogether volatile, the Alkalizate fix'd. […][35]

[30] CWS, I, 174.
[31] CWS, I, 210.
[32] CWS, I, 325.
[33] CWS, I, 439-446.
[34] CWS, II, 423.
[35] WOB, 2, 105–106.

However, at that moment, Glauber had already written in the fourth part of his *Prosperitatis germaniæ* (1656-61) - which had been published in Latin in 1660, one year before Boyle would publish *De nitro* - the following:

N.B. The acid Spirit of Niter doth not dissolve sulphureous subjects, but mercurials onely : Contrarywise, the fix Niter doth not seize upon mercurial subjects, but sulphureous ones; but the flame of Salt-peter performs both : which verily is wonderful, that things so unlike should in some few hours time be extracted out of one and the same subject. For the corrosive Spirit prepared out of Salt-peter by Distillation, and likewise the fix Salt, are most bitter enemies to each other, which ruinating and flaying one another, and being dead, return agen unto that which they were afore, and partakes of both natures; which the Ancient Philosophers do clearly point out unto us by the Griffon, which is headed and winged like an eagle, and the hinder part of its Body like a Lyon, as we have mentioned more at large in foregoing third part of the Prosperity of *Germany* (Glauber 1689, 406).

Clericuzio writes in *Elements, Principles and Corpuscles* (2000) that J.R. Glauber was "The most important and influential German chemist in the mid-seventeenth century" and that he "spent many years in the Netherlands and established laboratories both in Germany (Kissingen) and in Amsterdam.". (Clericuzio, 200, 192) He does not mention Glauber in his writings on the Boyle/Spinoza controversy. However, obviously, the decomposition and recomposition of saltpeter is already described in the citation from Glauber's work. Moreover, the conclusion that Boyle had made from this experiment – that one substance (niter) can be decomposed in two different substances which were fundamentally different from saltpeter and can subsequently be recombined into saltpeter is already in Glauber's text. Indeed, in the passage above the German alchemist argues highlights very clearly that "fix Niter" is very different from "the corrosive Spirit prepared out of Salt-peter by Distillation, and likewise the fix Salt, are most bitter enemies to each other". Acid spirit and fixed niter are "two fightening and capital Enemies", he continues, highlighting that in his view they were two very distinct substances (and different from saltpeter) with different qualities: the acid spirit of niter that does "not dissolve sulphureous subjects, but mercurial onely" and "fix niter doth not seize upon mercurial subjects, but sulphureous ones".



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oriundus artificiosè perficiet. NB. Spiritus Acidus Nitri Sulphurea Subjecta non solvit, sed tantum Mercurialia : E contrario Fixum Nitrum non Mercurialia, sed Sulphurea Subjecta aggreditur: Salispetræ verò flamma utrumque præstat: quod profecto est mirabile, quod ex uno eodem subjecto aliquot horarum intervallo tam dissimiles res eliciantur. Etenim ex Salepetræ per destillationem Spiritus Corrosivus, ac etiam Sal fixus parati inimicissimi inter se sunt hostes, qui in mutuam cædem ruentes, & mortui redeunt ad id, quod anteà, utriusque Naturæ participem, quod Veteres Philosophi nobis apertè significant Gryphone Aquilæ caput & alas, ac Leonis corpus posterius habente, ut in præcedente Tertiâ Parte Prospetitatis Germaniæ pluribus meminimus.

Eum, qui hanc Veterem de Gryphone, Leone, & Aquilâ Fabulam rectè intelligit, Sol illustrat, haud exiguam utilitatem sibi inde acquisiturum. Quicquid Aquila corrosiva solvit & dilacerat, illud fixus, & igneus Leo præcipitat; Ac quicquid Leo deglutit, illud ipsi Aquila rursus eripit, mutuâ tamen cæde se conficientes, ex quorum corporibus mortuis existit Grypho, qui Aquilæ & Leonis corpus habet. Quantò sæpius hic labor iteratur, tantò major potentior, & fortior Grypho evadit, si prius cum Aquilâ, tum Leo vili cibo se saturaverint, & pinguefacti fuerint: Aut quantâ magnitudine Aquila & Leo antè pugnandum ex subjectis sibi aptis & commodis accreve-

Fig. 1: Extract from the original Latin version of the fourth part of Glauber's *Prosperitatis germaniæ* (1656-61) which included the redintegration experiment.

Consequently, the question arises whether Boyle borrowed the experiment from the German alchemist and applied it in favor of his own agenda. In the last section (*section XL*[36]) of his *De nitro* and in the preface[37] (which he completed around 1660 just before its publication) of this work, he tries to convince his readers that he had only flipped through Glauber's book and had executed the redintegration experiment long before Glauber. However, as several Boyle scholars have already

[36] See WOB, 2, 158.
[37] See WOB, 2, 88-90.

argued, he is not trustworthy. Moreover, as William R. Newman and Lawrence M. Principe have indicated, Boyle had already in other works such as his "*The Booke of Nature*" (c. 1649) used Glauber's *Novi furni* (1646-47) as a source. (Newman & Principe 2005, p. 212-213) Furthermore, W.R. Newman argues that Boyle is not always "straightforward in the representation of his sources". And Michael Hunter confirms that "literally interpreted", Boyle is sometimes "somewhat dishonest". (Hunter 2000, p.135-156)

For several reasons, it is much more likely that Boyle knew about Glauber's experiment and had used it in order to demonstrate the plausibility of his own new philosophy. This thesis, however, could be contested by pointing out that Boyle had indeed published his work indeed in 1661 but had written it in the late 1650s[38] before Glauber had published his experiment. However, Glauber and Boyle were both members of an international network around Samuel Hartlib (ca.1600-1662), the so-called Hartlib circle. Consequently, they were in contact with each other via Glauber's contact person Johann Moriaen and other Hartlibians. Hartlib himself was already from 1643 onwards very interested in Glauber's work and even hoped that Glauber would come to England. (Webster 1975) On a regular basis, Moriaen sent him Glauber's writings which he translated and distributed among his members, including Robert Boyle. (Young 1998, p.182-216) Not only Glauber's publications but also his equipment was brought to England by Hartlibians and replicated there. Interestingly, Hartlib wrote in 1656 already just after the publication of the first parts of the *Prosperitatae Germaniae* [*Teutschlands Wolfahrt*] that "the annexed discourse of saltpeter *De nitro* is the most substantial rational et real piece, wherein many secrets are discovered which himself [Boyle] had before."[39] Secondly, on the demand of Dury and Hartlib himself, another Hartlibian with whom Boyle was in contact, Benjamin Worsley (1618-1673), had visited Glauber's lab in 1648-49 in Amsterdam. So, he must have known about Glauber's experiment. Worsley even wrote in the 1650s book entitled, *De nitro theses quaedam*, wherein he described Glauber's experiments on nitre. Boyle knew this book and was in contact with Worsley. Thirdly, Robert Boyle was in 1648, in Holland, at the time Worsley was visiting Glauber. Consequently, it is even likely that - at that moment already being interested in chemistry - he might have heard of the activities that took place in Glauber's impressive lab which was at that time not only one of the most well-known labs in Europe but also a discussion room.

b. Glauber's Paracelsian interpretation

In Glauber's times, there was no question yet of modern chemistry. Therefore, the early chemical engineer expressed himself in his numerous writings in technical language referring to practical lab skills and applications. Very remarkably, he made also use of powerful mythological images to

[38] See WOB, xii.
[39] HP 29/5/92B.

express his views on the redintegration process. Saltpeter, he writes, is like the Griffin which is a non-existing mythological creature with the head of an eagle and the body of a lion. In 1660 a book was published which can be regarded as the first Dutch encyclopedia of animals. Glauber must have had have such an image in mind when he wrote about niter:

Fig.2 A picture of a Griffin, published in 1660 in Amsterdam in the first Dutch encyclopedia of animals.[40]

The Griffin was traditionally considered to be an especially powerful and majestic mythological creature because the lion was traditionally considered the king of the beasts and the eagle the king of birds in ancient Persia. In antiquity, it was a symbol of divine power and a guardian of the divine. Hence, the early industrial chemist used this mythological figure to express his views on the properties of saltpeter which he considered to be fabulous.

The application of these kind of mythological creatures may sound pre-scientific. However, it is interesting to notice that mythological animals such as the Griffon are still used in contemporary chemistry to clarify the real structure of substances such as benzene (C_6H_6). The real structure is in textbooks[41] presented as a cross between two non-existing mythological animals. For instance: A rhinoceros (real animal) as a cross between a griffin (imaginary) and a unicorn (imaginary) neither of which exists outside of mythology.

[40] Picture by the engraver Matthias Merian from: Jonston, John, *Naeukeurige beschryving van de natuur der viervoetige dieren, vissen en bloedloze water-dieren, vogelen, kronkel-dieren, slangen en draken* (Dutch translation by M. Grausius of the Historiae naturalis). Amsterdam: I. I. Schipper, 1660. This Dutch translation has been published three years after the publication of the original, Latin text.
[41] For an example, see: Chang, Raymond, Physical Chemistry for the Biosciences. Sausalito: University Science books, 2005, 466.

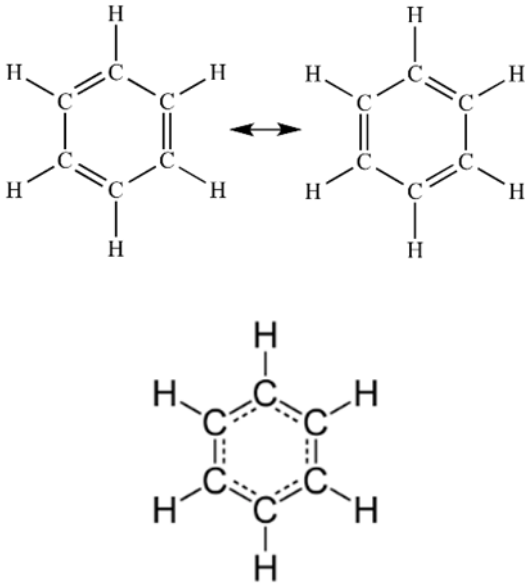


Fig. 3: Below: a representation of the real structure of benzene as a combination of the two imaginative structures above.

In Glauber's presentation, the Griffon stands for the "hermaphroditic salt" saltpeter, the eagle for the volatile acid spirit of niter and the lion for the fix niter so that the redintegration experiment can be represented as follows:

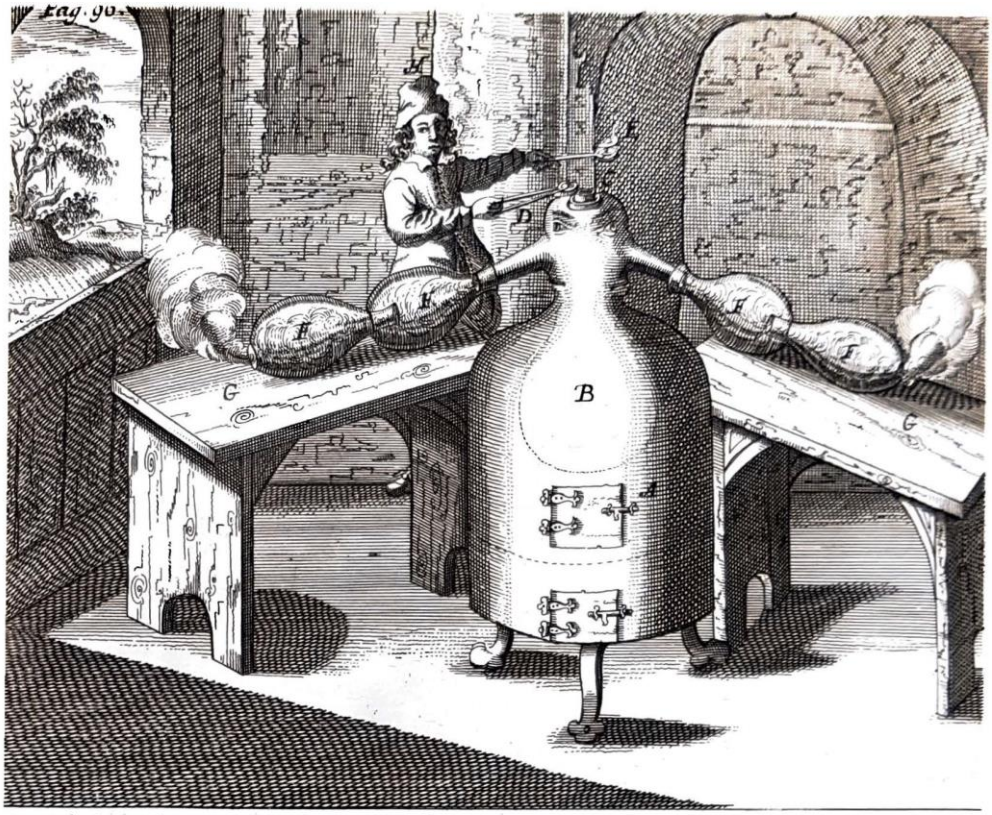
STEP I: Griffon (saltpeter) -> Eagle (Spirit of Niter) + Lion (fix Niter)

STEP II: Eagle (Spirit of Niter) + Lion (fix Niter) -> Griffon (saltpeter)

Saltpeter can be transmutated by what he calls "distillation" into "two fightening and capital Enemies": corrosive spirit and fix Salt. The acid spirit of niter does "not dissolve sulphureous subjects, but mercurial onely" and "fix niter doth not seize upon mercurial subjects, but sulphureous ones". It is important to notice that the qualities that Glauber mentions (which make the difference) are now both considered to be 'chemical qualities': being acid and corrosive, causing substances to precipitate, being capable to transmutate different substances, etc. So, Boyle did not introduce the supposed 'chemical qualities' in his interpretation to give a 'chemical interpretation' of the phenomenon. But it is necessary to remark that the distinction between chemical and physical qualities is in this historical context quite anachronistic.

Glauber treats also the second step of the redintegration reaction, the reversed transmutation: "the two enemies" to each other, he continues, can transmutate again to saltpeter: "which ruinating and flaying one another, and being dead, return agen unto that which they were afore, and partakes of both natures". (Glauber 1689, p. 406)

Johann Rudolph Glauber distinguished three different "forms or shapes" of saltpeter as he put it. The author of *Novi furni philosophici* (1646-47) did not only consider saltpeter to be a compound which could be produced starting from waste material. This material was widely available so that saltpeter could subsequently be applied in numerous agricultural and pharmaceutical products in order to contribute to the prosperity of Germany after the Thirty Years War (1618-1648). Moreover, a combination of these three forms constituted, in his view, the universal dissolvent, Van Helmont's *Alkahest*: "for my part I remain constant in my Opinion, and say, that saltpeter is an universal Dissolvent, and is able to dissolve all the things in the whole World, if it be made use of in three forms or shaps" (Glauber 1689, p. 406). He described the properties of saltpeter not only in his *Prosperitatae Germaniae* but also in other works he published earlier (e.g. *Miraculum Mundi* (1653-1658)) which caused much interest among early chemists such as Boyle.



A. Ist der Ofen.
B. Das distillier gefäs in dem Ofen.
C. Das löch mit einem faltz dardurch das swänge eingetragen wird.
D. Die Zange mit deckel darmit das gefäs nach dem eintragen geschlosse wirdt.
E. Ein eisen löffel darmit der schwam eingetragen
F. Die recipienten.
G. Die banck darauf die re-
enten ligen.
H. der Laborant.

in Continuatione miraculi mundi

Fig. 4: Images included in Glauber's *Miraculum Mundi* (1653-1658), giving an impression of his lab. (Glauber 1689, 188)

c. Boyle's "truly Philosophic and perfect Analysis of Niter"

As I have shown, Boyle made basically the same conclusion as Glauber. Nevertheless, there are very important differences between Glauber's interpretation and Boyle's. Glauber explained the redintegration process by making use of imaginative metaphors, and a distinction between the three forms of salt-peter based on Paracelsus's three alchemical principles sulphur, mercury, and salt.

As Clericuzio writes in his *Elements, Principles and Corpuscles* (2000): Glauber "made no use of corpuscular theories in his chemical work". Boyle, by contrast, gave an intelligible systematical interpretation within the conceptual framework of his corpuscular philosophy; that's why he called the redintegration process a "Philosophical Redintegration" opposed to Glauber's "Chymical Purification".

The autodidact Glauber was an extremely skilled practical chemist but he was not a theorist and certainly not a corpuscular philosopher. Boyle, by contrast, was exceptionally systematic and was one of the first to formulate and practice a method of consistent skepticism and experimental verification, as J.T. Young put it (Young 1998, p. 185).

As Boyle had explained in the preface of his *De nitro* (and also later, for instance in *Of the Imperfecion of the Chymist's Doctrine of Qualities*) he wanted to get rid of the chemistry based on Paracelsus's ideas. Therefore, he gave Glauber's experiment and the phenomena that went together with that experiment a mechanical interpretation. In conclusion, he used the experiment of 'the Paracelsus of the seventeenth century' to illustrate and promote his new corpuscular philosophy.

d. Spinoza's interpretation

Opposed to Boyle and Glauber, Spinoza argued that during the redintegration process saltpeter was not analyzed into two different substances which differed fundamentally from saltpeter and from each other:

STEP 1 : Salt-petre (nitre) [*Nitri*] -> volatile nitre [*Spiritus Nitri*] + fixed nitre [*salis fixi*]

STEP 2 : Volatile nitre [*Spiritus Nitri*] + fixed nitre [*salis fixi*] -> Salt-petre (nitre) [*Nitri*]

By contrast, the Dutch philosopher concluded that *Nitri* and *Spiritus nitri* were only different states of one and the same compound. In his view, the only difference between saltpeter and spirit of nitre is that the parts of saltpeter are at rest, whereas the parts of volatile nitre are in motion. Furthermore, as he argues, fixed saltpeter is not a significant part of nitre, but an impurity [*Foeces Nitri*]. Instead of being a compound that plays an active role in the experimental transformation, he insists that it is only an '*instrumentum*' [*tanquam instrumentum adhibetur*], which is comparable to what we know today as a catalyst (i.e. a compound that facilitates a reaction without directly participating in or being altered by it). In sum, Spinoza gives a mechanical interpretation of the experiment which lead Clericuzio to conclude that Spinoza is a radical and strict, reductionistic mechanical philosopher. This straightforward conclusion, however, can be contested in several ways. First of all, how can we possibly explain that the Dutch philosopher had - even later in his career, when his philosophy was in a more developed stage - a genuine interest in the alchemical question of the transmutation of metals if he was a strict mechanical philosopher who excluded all 'chemical' transformations from one compound into another? Based on his *Letter 40* (1667) to Jarig Jelles, there is historical evidence that Spinoza took the alchemist's claim that silver and lead could be transmuted into gold seriously; that he discussed this question with his friends, that he visited alchemists such as the goldsmith Berchtolt (or Berchtelt) and Helvetius to figure out whether what he had heard was true. As Raphael Patai put it in his "*The Jewish Alchemists*" (2014): "This in itself shows that despite his considerable knowledge of the sciences and his great critical acumen, Spinoza, a man of his time, considered transmutation at least a possibility." (Patai 2014, p. 398)

Secondly, it cannot be excluded that Spinoza's interpretation of the experiment does not exclusively express his own thoughts but is rather meant to challenge Boyle and find out whether the co-founder of the Royal Society could explain the entire phenomenon based on his new mechanical philosophy that he defended so proudly. That would explain why, for instance, Spinoza writes in *Letter 13* that he did not have to prove whether fixed niter is just an impurity in niter. He just assumed this, he clarifies, to figure out whether the "Distinguished Gentleman" was able to prove his own interpretation[42].

Clericuzio's conclusion that Spinoza is a reductionistic, strictly radical mechanical philosopher is even problematic for other reasons. The term 'mechanical philosophy' is not always well defined in secondary literature. However, Boyle gave a precise definition which expressed very clearly what his contemporaries understood by this term. Obviously, most of the elements (1, 2, 6 and 7) of that definition are problematic for Spinoza. First of all, Boyle's mechanical principles only apply to the corporeal world for Spinoza and not for nature as a whole which in his view implies all existing

[42] See CWS, I, 208.

things, ideas included. Secondly, as he pointed out in his *Letter 81* (1676) to E.W. Tschirnhaus there is no passive or inert stuff according to Spinoza. In other words: there is no 'matter and motion'; there is only matter-in-motion or motion-in-matter. Furthermore, for each body there is a corresponding idea, and as Spinoza writes several times in his *Ethics*: idea and body are one and the same thing. So, in that sense, a body can never be reduced to something strictly materialistic. Thirdly, there is the machine analogy. Contrary to his contemporaries whose work he knew well such as Chr. Huygens and R. Descartes, Spinoza never applies in an explicit way man-made machines such as clocks as an analogy for nature as a whole and bodies in particular. Fourthly, there is the epistemic status of Boyle's theory of qualities which - as this paper has shown already - was contested by the Dutch philosopher.

Conclusion:

This paper has shown that the redintegration experiment - which gets a central place in the comments of the Boyle/Spinoza correspondence – must be understood in the light of Boyle's illustration, defense and promotion of a new philosophy: The Corpuscular Philosophy.

Boyle borrowed an experiment from the German alchemist/chemist Glauber in order to illustrate the plausibility of his new philosophy. The author of "*The Sceptical Chymist*" did not really introduce new 'chemical qualities' to the substances and drew basically the same conclusion as Glauber. However, Boyle interpreted the experiment within another conceptual framework. Boyle expelled the influence of Paracelsus and the metaphor of the Griffon from Glauber's interpretation and gave the experiment a mechanical interpretation. This experiment allowed him to demonstrate that saltpeter - which he regarded as a paradigmatic example for all substances - could be decomposed and recomposed just as a pendulum clock. Contrary to what Clercicuzio writes, Boyle made obvious attempts to demonstrate that all the sensible phenomena (or secondary qualities) that went together with the experiment could be explained in terms of mechanical properties of the corpuscles.

Spinoza could hardly believe that it was Boyle's aim to illustrate his mechanical theory of qualities. Therefore, he started to comment on the nature of saltpeter and Boyle 's methodology. Contrary to what Clericuzio has argued, he did have a problem with Boyle's experimental methodology, which he regarded as unscientific. Instead he preferred ordinary experience as a starting point for adequate knowledge. As for the nature of saltpeter, Spinoza contested indeed Boyle's conclusion that saltpeter was recomposed into two different substances which differ from saltpeter.

However, this may not lead to the straightforward conclusion that Spinoza is a strict mechanical philosopher who excluded all transmutations from a body into another body. It is important to notice

that the concept of "affection" between bodies is essential in Spinoza's ontology and that his system allows that a body can be altered into another body. Moreover, as his correspondence illustrates, Spinoza took the transmutation of metals very seriously. As this paper has shown, categorizing, Spinoza as a reductionistic, radical mechanist, as Clericuzio does, is also for several other reasons problematic.

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