THE PURLOINED REFERENT: LAVOISIER AND THE DISAPPEARANCE OF *PHLOGISTON*

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Abstract

In this paper, I challenge the long-established view that the term *phlogiston* fails to refer. After a close examination of the reference of *phlogiston* during Lavoisier's Chemical Revolution, I show that it referred throughout to a natural substance, *fire matter*. I state that Lavoisier eliminated the term but not its referent, which he re-named *caloric*, and I claim that it is in the historical and cultural context of the Chemical Revolution that the Lavoisier's intentions can be understood.

KEY WORDS

Phlogiston; Chemical Revolution; Lavoisier; reference; referent.

1. Introduction

The fate of *phlogiston* was also the fate of many other terms of the History of Chemistry before the publication of the *Méthode de la nomenclature chimique* by Lavoisier et al[1] in 1787: *spirit of vitriol*, *mineral chermes*, *oropiment*, *saffron of Mars, Argentine flower of* *antimony*, *tartar acid*, to name but a few. Whereas *oropiment* no longer denotes, *phlogiston* still denotes, if not a substance found in nature or isolated in a laboratory, at least something in which chemists believed, during a period in the history of Chemistry. However, it is almost a topic in texts on the History and Philosophy of Science that the term *phlogiston* fails to refer. It is generally accepted that it does not refer to a substance, but it is also a common belief that the term *phlogiston* denotes that substance that 17th and 18th century chemists actually believed to exist, and which was defined in many – perhaps too many—ways.

In this paper, I develop the idea that the term *phlogiston* did refer for a long time, and throughout the revolution initiated by Lavoisier; that *phlogiston* referred to a natural substance, *fire matter*. I claim that Lavoisier eliminated the term but not its referent, which he re-named "caloric". I will also show that Lavoisier never had the explicit intention that the referent of *phlogiston* should cease to exist, but rather intended to discard the term, substituting it by a different one. Finally, I suggest some of the reasons that might explain that explicit intention.

This paper also sheds light on the problematic relationship between Philosophy and History of Science post-Lakatos, often considered a repository of potential reconstructions that exemplify philosophical theses *à la mode*. This paper is inscribed within an alternative program that emphasizes a much richer relation between History and Philosophy of Science which is being promoted particularly by Chang (2004), called "Complementary Science" or "History and

Philosophy of Science as Science by Other Means", an initiative that I will develop in future works.

2. The term *phlogiston* and the notion of *failure to refer*.

Finding out which term – scientific or otherwise—fails to refer is for Eco (1997) an extremely complex business: both felicitous reference and failure to refer must be negotiated: there is no privileged access, free of human contingencies, to the reference of a term or the absence thereof. Causal theories of reference, for instance, provide a regulative (I would dare say normative) notion that reflects our concern about referring to the world by means of language: in order to refer to something, we need the regulative idea of an ontological reference. For Eco (1997), this regulative idea operates even when we refer to *impossibilia* or inconceivable objects. Given the fact that causal scholars have posited that we can refer to objects we would not know how to determine, recognize, locate or even interpret, it seems evident that we can also refer to inconceivable objects: we do use language in this way, simply because reference is one of the ways in which we *can* use language. Evidently this is not the case of the term *phlogiston*: phlogiston is neither inconceivable nor impossible, nor, alas, existent.

From a representational-physicalist point of departure (Devitt and Sterelny 1987), a term fails to refer if it has no ontological grounds. *Phlogiston* fails to refer because it has no physical existence. The question is: who can assert that phlogiston does not exist?

Nowadays, everyone does, fundamentally and primarily because science (and not merely Chemistry) has established it as a fact. The process that led to this result is extremely complex, lengthy and multi-dimensional. It involves factors of several kinds: cognitive, social, political, historical, as well as *ontological*, and this is the only wedge I will drive in this thorny mass. I will not assert that phlogiston once existed and then ceased to exist, as is the case with dinosaurs, mainly because determining what exists and what does not exist must be found out through a very laborious process of scientific research. We could say that science allows us to snoop into what exists and what, sometimes mistakenly, is *supposed* to exist. This inquiry demands that we take sides with the "referents" and follow their journey, even when they end up not being physical-existent or existing objects.[2]

According to Stahl,[3] a particular principle -- *phlogiston* or "fire matter"-- was released when combustible bodies were subjected to a pronounced increase in temperature. This fire matter is emitted in combustion, in the form of flame and heat. Combustible bodies are therefore *constituted* by that substance, together with a considerable amount of "earth". When metals are heated, they lose this substance, turning into metallic calx. Metals are, according to Stahl, combustible bodies formed by the union of one earth or calx and the inflammable principle. Reciprocally, adding phlogiston to a metallic calx would be enough to rebuild the primitive metal, and this was an experiment frequently carried out by Stahl himself and later chemists. In fact, this was possible by heating the calx with a combustible body such as oil, charcoal or sulfur, all of them particularly rich in phlogiston. In this way, the theory of phlogiston not only related the formation of metallic alkali to combustion, but it also made it possible to link the heating of bodies with the production of flame and heat and with animal breathing, which was supposed to serve to exhale the phlogiston fixed in the human body. Thus a multitude of diverse phenomena were gathered in one and the same general conception.

Phlogiston also had the power to transport itself from one body to another, conveying to its host the property of being inflammable. According to Marcellin Berthelot, one of the defenders of Lavoisier's Chemistry, this theory -- "so clear, so in accordance with general appearances" (Berthelot 1890 p.35) -- was abandoned with reluctance. Only Priestley and la Métherie remained obstinately faithful to it throughout their lives. Cavendish, another prominent English chemist, did not dispute Lavoisier's "anti-phlogistic" theory but he did not commit to it either, as was the case of several other European chemists throughout the 18th century. The most remarkable case is possibly Kirwan, who fiercely fought against the phlogiston theory for some time, made some extremely relevant discoveries, and ended up by declaring in black and white his conversion to Lavoisier's theory.

Most historians of the Chemical Revolution of the 18th century seem to agree that the discovery of gases other than ordinary air -- ignored until the second half of the 18th century-- changed the face of Chemistry, introducing a huge and completely unexpected amount of data. In 1767 Cavendish proved the existence and determined the characteristic of inflammable air, a new gas which, thanks to Lavoisier, we can identify today as hydrogen. Between 1771 and 1774 Priestley manage to isolate and name "the main gases known today" (Berthelot, 1890. p. 39), including "dephlogisticized air" or oxygen base according to Lavoisier's nomenclature; "nitrous air" or nitric oxide as Lavoisier called it, and "dephlogisticized nitrous air". These findings had a great impact on the community of Chemists, since they made it possible to abandon the old conception according to which air was a simple element (together with earth, water and fire). With this discovery, the idea that air was a substance in a certain state, a state of matter, that the gaseous state was a physical and not a chemical phenomenon, began to gain acceptance.

Whereas Priestley experimentally observed that air decomposed, he interpreted this phenomenon as a combination of air with phlogiston or fire matter: the phlogiston theory seemed to benefit from this interpretation, since the principle, until then invisible, could be equated to an experimental reality. Hence phlogiston becomes the principle of fire responsible for combustion, and its release would explain the heat and light produced in this process. It is invisible, it is concealed, and it is impossible to isolate, because it is always found fixed to an earthy substance.

Stahl's doctrine is often reduced, even by Lavoisier, to phlogiston theory, even though it is much further-reaching. Several historical studies, among them those of Pierre Duhem (1902), Emile Meyerson (1902) and Hélène Metzger (1930, 1933, 1935), insist that Stahl's

Chemistry constituted an important system – the first chemical system adopted throughout Europe—which made it possible to explain a large number of phenomena, among them those mentioned above. But above all, Stahl's Chemistry is grounded on a philosophy of matter which, even though it is corpuscular, is opposed to mechanism. According to Bensaude-Vincent (1989), Stahl admitted the existence of indivisible particles, but he resisted the idea of a single, uniform matter.

> Thanks to Stahl's success, the old conception of elements-principles, universal components of matter and carriers of its features, is still in force during the 18th century. It is not a relic of an exhausted alchemical tradition but the grounds of an ambitious chemical science, keen to affirm its originality. (Bensaude-Vincent, 1989, p. 419, my translation)

Let's bear in mind that the four elements are then not vague principles, something like supports of properties; on the contrary, they are defined as simple bodies, accessible to experience. How did Lavoisier come to question the theory of phlogiston? Historians of the chemical revolution -- with the exception of the so-called relativists, including Kuhn -- attribute this to an experiment and to the scales or weight system that Lavoisier relentlessly applied. Lavoisier was working on the relation between air and fire, and after several readings he adopted the idea that every substance can exist in the three states of aggregation –solid, liquid or gaseous— depending on the quantity of *fire matter combined*.

Even though from 1772 to 1782 Lavoisier conceived a revolutionary project – according to Figuier (1879), Berthelot (1890) and Bensaude-Vincent (1989) - he did not express himself immediately in those terms; he would wait until 1787 for that. His publications against phlogiston are extremely prudent. In his account *Mémoire sur la combustion en générale (*1777*)* he points to the need to go beyond facts when it comes to formulating hypotheses, and he presents his own, the result of an inductive, generalizing methodology, based on a series of methodically conducted experiments, with precise measurements, repetitions, variations and verifications. In his theory of combustion, however, one cannot yet observe the suppression of the elements-principles Lavoisier needs to explain the *release of heat and light in combustion*, which he ascribes to a release of the caloric contained in air.

It is usual to affirm that antiphlogistic theory is the opposite, the inverse, of phlogiston theory. It is also usual to state that phlogiston theory posited that something was always liberated in combustion and that, on the contrary, Lavoisier's theory posited that in every combustion something is absorbed. From this perspective, *grosso modo*, it does seem that the two theories oppose each other. On closer scrutiny, however, it takes a much more thorough understanding to see where the inversion lies.

In logical terms, from the fact that in combustion something is absorbed it does not necessarily follow that something else cannot be released, and reciprocally, from the fact that in a combustion something is released, it does not necessarily follow that something else might not also be absorbed. In order to elucidate the inversion what matters the most is *what* phlogiston was and *where* it was found: phlogiston was fire matter and was found *in* combustible bodies. If a combustible body combusted, it liberated the fire matter *it contained*, that is to say, it emitted heat, light and/or flame. For Lavoisier, phlogiston did not exist *in* combustible bodies: in a nutshell, what Lavoisier denied was not the material existence of phlogiston but rather one of the tenets of phlogiston theory, namely that fire matter was *contained* in combustible bodies. He was opposed, then, to the idea of the *presence* of fire matter *in* combustible bodies. But he also affirmed that in every combustion a new body was fixed, namely the base of *élan vital* or oxygen: combustible bodies did not contain phlogiston --which does not mean that it did not exist-- and when they combusted they absorbed the base of *élan vital* or oxygen, liberating fire matter, or caloric, or light, or flame, or all of the above. Indeed, so far there are no opposites. Another claim of Lavoisier's will be necessary to understand what the opposition consisted in. For Lavoisier, the cause of combustion and heat release was the fixation of the base of the *élan vital* or oxygen in the bodies, whereas for Stahl the cause of combustion was phlogiston, that is to say, the fire matter that was one of the constituents of combustible bodies together with other, generally earthy, substances. Lavoisier denies the *presence* of the fire matter *in* combustible bodies and denies that the cause of all combustion should be phlogiston, *but he does not deny the existence of the fire matter*, and hence he needs to find another *cause* for combustion –in this case, oxygen— without denying the evident: that combustion produces, emits, releases, heat, light and/or flame (and smoke, in the combustion of organic materials). Something is released in combustion, not just for supporters of the phlogiston theory so ridiculed by Lavoisier in *Réflexions sur le phlogistique* (1783). From the fact that Lavoisier would not deny the existence of fire matter it does not follow either that it should have a place in his system; he could simply neglect it, fail to introduce it in his theory. But indeed this was not the case. Where did fire matter end up? In order to answer this question, I will have to concentrate on two of Lavoisier's works: his *Mémoire sur la combustion en générale (1777)* and *Réflexions* (1783).

In Lavoisier (1777) we come across the four constant phenomena which he believes obey "laws by which nature always abides" (1777 p.226). The first three are:

1. "In all combustion the fire matter or of light matter is released" (1777p.226).
2. "Bodies cannot burn but in a small number of kinds of air, or rather, there cannot be combustion but in one kind of air, that which Priestley has named *dephlogisticized air* and I shall here name *pure air*." (1777p.226)
3. "In all combustion there is destruction or decomposition of the pure air in which combustion takes place, and weight of the burnt body increases in proportion to the quantity of destroyed or decomposed air". (1777 p.227)

Lavoisier immediately adds that,

> ... these different phenomena of calcination of metals and combustion are explained in a *quite felicitous* manner in Stahl's hypothesis; one must suppose, as he does, that there is matter of fire, phlogiston, *fixed in metals*, in sulfur and in each one of the bodies he considers combustible. But if one asks the followers of Stahl's doctrine to prove the existence of fire matter *in* combustible bodies, they necessarily fall into a vicious circle and are forced to answer that combustible bodies contain fire matter because they burn, and they burn because they contain fire matter; it is easy to see in this last analysis that this amounts to explaining combustion through combustion. (1777 pp. 227-228 italics added)

It is easy to see the depth of Lavoisier's logical –fundamentally logical-- misgivings against the followers of "Stahl's doctrine". Both Figuier (1879) and Berthelot (1891) insist emphatically on this point. The former considers Lavoisier (1783) "a masterpiece of logic", if not of Chemistry. Someone might pause to reflect on this insistence and wonder if a revolution might be a mere *inversion*, or even what caused an *inversion* to become a scientific revolution. The first question shows perplexity; indeed, several historians of science have affirmed that the radical change (what is an inversion if not this?) that took place in the history of Chemistry would never have constituted a scientific revolution without the acknowledgment of the manifest, explicit, and consistent *intention* of *its* author, Lavoisier.

> The existence of fire matter, phlogiston, *in* metals, sulfur, etc., is therefore no more than a hypothesis, an assumption which, once admitted, explains, it is true, some calcinations and combustion phenomena; but if I show that those *same* phenomena can *also* be easily explained by the opposite hypothesis, that is to say, without

> supposing that neither fire matter nor phlogiston, exists, *in* bodies *called* combustible, Stahl's system is shaken to its foundations. (1777 p.228, italics added)

Surely someone might like to ask Lavoisier what exactly he understands by the "fire matter, or phlogiston" he mentions in the previous passage and in many others. Lavoisier would answer "with Franklin, Boërhaave and some of the philosophers of Antiquity, that the fire matter or of light is a very subtle, very elastic fluid, that enfolds our planet, penetrating more or less easily those bodies that compose it and tends, *when it is free*, to balance in all of them). (1777 p.228, italics added).

Lavoisier refuses to abandon this definition, even in the *Traité élementaire de chimie* of 1789, his last work; it belongs to his system, it plays an important part in it, and he will *intentionally* redub this referent as "caloric". Fire matter is everywhere and it constitutes one of the imponderable matters, the imponderable matter *par excellence*; in fact, Lavoisier is known as the first scholar to posit the distinction between ponderable and imponderable matter. However, there is a particular state, the aeriform state, (neither solids nor combustible bodies-- the reader will recall that when Stahl developed his theory *gases* were not known) that needs fire matter:

> . . . every aeriform fluid, all kinds of air, *are the result* of the combination of any body whatsoever, solid or fluid, with the fire matter or light, and aeriform fluids owe to this combination their elasticity, their specific lightness, their faintness and all the other properties that make them close to igneous fluid. … The same

> happens to air during combustion, the body that is burnt takes away its base; then the fire matter, which served as solvent, is released, it claims back all its rights and it escapes with its known features, that is *with flame, heat and light* (1777 p.229, italics added).

Fire matter is no longer combined with earths, it is combined with airs. The *élan vital* is a combination of oxygen, or base of the *élan vital*, and fire matter. Every air will be for Lavoisier the combination of fire matter and the body in its gaseous state which will form the gas *base*: there is no gas without fire matter, hence one can hardly consider dephlogisticized air –pure air, as Lavoisier calls it—an air. For a substance to be aeriform it must be combined with fire matter or phlogiston, hence Lavoisier's belief that Priestley *improperly* named that air "dephlogisticized air", not because of its linguistic and conceptual associations but because it did not exist. In Lavoisier's nomenclature, it corresponds to the base of *élan vital* or oxygen (pure air, as he called it in 1777), not to *élan vital* itself, and of course oxygen or base of *élan vital* is far easier to breathe than *élan vital* itself. Hence Lavoisier has no objections to the word "dephlogisticized"; his problem lies with the notion of "air": it is unlikely for an air not to be combined with fire matter.

> Pure air, Priestley's dephlogisticized air, is therefore, in my opinion, the true combustible body and perhaps the only one in nature, and it can be seen that, in order to explain combustion phenomena, there is no longer any need to assume the existence of a large amount of *fire fixed* in all the bodies we call *combustible* and, on the contrary, it is very likely that there might exist in small quantities in metals, sulfur and phosphorus and in most very solid, heavy compact bodies; and it is still possible that in these substances there might not exist but *the free*

> *fire matter*, in virtue of the property It has of balancing with the bodies that surround it. (1777 p.231)

This conceptual change where fire matter is not fixed but combined, will allow Lavoisier to develop one of his most important contributions: the notion that matter (which is always conserved for this author) can present itself in three states of aggregation, liquid, solid or gaseous, and if this is so, it is thanks to the participation of free fire or fire matter:

> These three states do not depend on anything other than the greater or lesser amount of fire matter that penetrates those bodies and is combined with them. Fluidity, vaporization, elasticity are, therefore, the characteristic properties of the *presence* of fire and of a great amount of it; on the contrary, solidity, compactness, are proofs of its absence. Likewise, it is proven that aeriform substances, and air itself, contain a large amount of combined fire, it is also likely that solid bodies contain it in small amounts. (1777 p.231, italics added)

The *referent* of phlogiston is still present in antiphlogistic Chemistry. The multiple senses that the term *phlogiston* had during the sixty-year heydays of phlogiston theory, however, are no longer to be found. Almost all the descriptions of phlogiston elaborated with the purpose of saving it from *contradiction* and *principle begging* disappear in Lavoisier's system, but fire matter does not. Some of its properties, too few actually, change -- for instance, it is not fixed but combined-- but the main changes are its *function* and *location*: it is no longer found in combustible bodies (since they tend to be solid) but rather, and in important quantities, in aeriform fluids or gases. It will no longer be the cause of combustion but it has an important participation in it, to the extent that it makes of *élan vital* or oxygen, according to Lavoisier, the universal cause of combustion. It would still take many years for heat to be considered an interchange of thermal energy, and to this day there is disagreement about what the nature of fire actually is.

This interpretation could be challenged by arguing that fire is material but not substantial, that Lavoisier was certain about its materiality but not about its substantiality. The only justification for this interpretation is the idea that fire is an imponderable body, and since substances tend to have extension, fire matter would not be a substance.

Lavosier, however, considered fire matter to be substantial; in *Réflexions* (1783), the substantiality of fire matter is determined with precision: fire is an element, and not in the sense of "principle or component of all things", but in Lavoisier's sense, namely that an element is a simple, even indivisible substance, which can sometimes be measured and manipulated, combined, extracted, etc., at will. Fire matter is a laboratory substance like many other elements, among them oxygen; Lavoisier (1783 p.627) adds: "… this element, this subtle fluid, probably obeys, like all the others, the laws of attraction, but its weight is so slight that it cannot be revealed by means of any physical experience".

In any case, it cannot have been easy for an experimentalist like the French chemist to deal with the nature of fire; he was convinced of its substantiality, but he could not prove experimentally how he knew this: weighing elements, reactions, residue, etc. Fire matter had weight but it was not measurable with the instruments available at the time. Lavoisier's conviction was so strong that he chose a curious metaphor to allude to the elemental character of fire matter, that of water. Fire does not dry, like air; for Lavoisier, fire "soaks", penetrates, invades, fills, saturates.[4]

> I could almost say that every body in nature is, with respect to heat matter, what a sponge is for water: if you squeeze a sponge you reduce the small cells that retain water; if you let them expand, they will immediately be able to contain more water. (1783 p.653)

This substantial feature of fire matter, of course, will be the Achilles' heel of anti-phlogiston Chemistry, but this won't happen until the end of the 19th century. The new name Lavoisier chooses to design fire matter, "caloric", does not change the *referent* of *phlogiston*; it only changes to some extent the *concept* of phlogiston, since it can exist in free or combined states and not just in a fixed state as Stahl believed. It also changes its name, and this for reasons and *intentions* very precisely established by Lavoisier. Below we shall look into what it is that Lavoisier rejects about phlogiston theory and how he does so.

3) **A minimal case study of a relevant difference: presence vs. existence.**

Réflexions starts with a reference to Lavoisier's great discovery; he states that by admitting his principle, the main difficulties in Chemistry "fade and dissipate and all phenomena are explained with surprising ease" (1783 p.623)

> But if in Chemistry everything is explained in a satisfactory manner without the aid of phlogiston, this only indicates that it is very likely that this principle does not exist, that it is only a hypothetical entity, a gratuitous supposition; indeed, it is a rule of good logic not to multiply entities needlessly. (1783 p.623)

Prima facie, this passage, quoted in most textbooks of the History of Chemistry, not only suggests but underscores the fact that, for Lavoisier, phlogiston is a hypothetical and gratuitous entity which, in virtue of good logic, calls for Occam's razor. However, the only thing Lavoisier denies is that phlogiston is fixed to combustible bodies; in other words, he denies the *presence in* bodies of phlogiston, but not its *existence*. Rather than confusing, the passage is biased. Lavoisier later affirms that the phlogiston hypothesis has been an "ill-fated mistake for Chemistry" (1783 p.673), that it has considerably hindered its progress – let us recall that Stahl's theory had barely been in force for sixty years, by all means a short period from a historical perspective—and this only due to "the flawed way of philosophizing it has introduced" (1783 p.623). Several historians of Chemistry agree that the phlogiston theory was historically and a logically a condition for Lavoisier's Chemistry, but the treatment it receives at the hands of the French chemist in the first pages of this work, would seem more fitting for alchemy than for phlogiston theory – something that several historians also point out.

Lavoisier continues this *Mémoire sur la combustion en générale* (1777) by begging the reader to forget that Stahl's theory ever existed, and follows this request with his own account of the phlogiston theory. According to Lavoisier, phlogiston theory only stated about combustion, "what the senses tell us: the release of heat and light" (1783 p. 624) In other words, that which is released in any combustion, *both for Stahl and for Lavoisier.*

> Nothing is more natural, in fact, than saying that combustible bodies burn because they *contain* an inflammable principle; but we owe to Stahl two important discoveries, independent of any system, any hypothesis, and which will be eternal truths; firstly, that metals are combustible bodies, that calcination is a true combustion. (1783 pp.624-625, italics added)

The other important universal discovery of Stahl's was, according to Lavoisier, that the property of burning can be transmitted from one body to another. From this Stahl inferred, in Lavoisier's account, that phlogiston could pass from one body to another and that it obeyed certain laws that were later called "affinities". However, says Lavoisier, Stahl did not explain a long-known phenomenon, verified by Boyle (1627-1691), namely that all combustible bodies gain weight after being burned or calcined. If when a body is burnt it releases phlogiston, metals should lose weight instead of gaining it. To solve this limitation, Stahl's followers posited a huge amount of *ad hoc* hypotheses and Lavoisier will criticize and destroy them one by one in this text – all except one: the sense that fixes the reference of phlogiston to the fire matter, heat and light --alas the single description perfectly observable!--: what is released, emitted, liberated in every combustion. After demolishing all the hypotheses that attempted to solve that limitation, Lavoisier laments that

> No matter how demonstrative the experiences I have used as support, it has become customary to doubt facts. Therefore, those who try to persuade the public that *everything that is new is false, or that everything that is true is not new*, have even found, in an ancient author, the seed of this discovery. (1783 p.629 italics added)

These exceedingly intelligent words will give place to the real criticism of the followers of the phlogiston theory, much more than of the theory of phlogiston itself, and to phlogiston *tout court*; in his criticism of Macquer, one of the most remarkable followers of the phlogiston theory in Lavoisier's time, he points out that Macquer ends up by appropriating his own finding to make it work in the phlogiston theory, something unacceptable for the self-nominated revolutionary, Lavoisier.

> It is surprising to see how Mr. Macquer, seemingly defending Stahl's doctrine in conserving the denomination of phlogiston, presents a completely new theory, which is not at all Stahl's: phlogiston, the inflammable principle, that weighty principle, composed by the fire element and the earthy element, is substituted by the pure matter of light; so *Mr. Macquer has kept the word without keeping the thing* and, pretending to defend Stahl's doctrine, he has conducted quite an attack on it. (1783 p.630, italics added)[5]

Lavoisier's actual criticism, in my opinion, is not aimed at what the phlogiston theorists had made of phlogiston, a "vague idea" that no-one had defined "rigorously", a designation under which irreconcilable and contradictory properties had fallen: phlogiston is a "true Proteus, shifting shapes all the time" (1783 p.640). Lavoisier was concerned with the reference of phlogiston, by the determination of its reference. On finding that phlogiston theorists had given the term so many modes of reference, Lavoisier changes the term *phlogiston* for "caloric" to refer to the same entity: the fire matter. The argument against phlogiston theory in *Réflextions sur de flogistique* is a logical and linguistic argument. In fact, by the end of this text, Lavoisier spells out once more the four phenomena present in every combustion, which he had already formulated in 1777, without conceptual changes of any kind. The only changes that can be observed are linguistic: the term "dephlogisticized" air has disappeared. Lavoisier finishes his 1783 *Mémoire* by stating that its aim was, among others, to show that "Stahl's phlogiston is an *imaginary entity* whose existence had been arbitrarily assumed *in* metals, sulfur, phosphorus, and *in* every combustible body" (1783 pp. 654-655, italics added).

Fire matter, in fact, emerges all the stronger from this *Mémoire*: it is not an imaginary entity, even though it may not be found in combustible bodies, but rather it surrounds all bodies, combined with the *bases* of gases and other solids, depending on its compactness, "soaking" everything, even Lavoisier himself, who no doubt breathed like every common mortal.

Since *phlogiston* refers to everything, for Lavoisier, both to "a" as to "not a", both to "b" and to "not b", it became necessary for the

French chemist to eliminate it and substitute it. Nothing happened, however, with the original referent of *phlogiston*; the fire matter continues to be studied by pneumatic Chemistry, or the Chemistry of Lavoisier, or modern Chemistry, or even antiphlogistic Chemistry.

4. The role of scientific language for Lavoisier.[6]

The lexical work of Guyton de Morveau and other 18th century authors culminated with the publication, in 1787, of an important work signed by four French chemists of the period: Antoine Laurent Lavoisier, Antoine Fourcroy, Claude Louis Berthollet and Guyton de Morveau himself. His *Méthode de la nomenclature chimique* contains a systematic set of rules to name substances based on Lavoisier's ideas, which, among other aspects, involved abandoning the theory of phlogiston and the consolidation of new ideas on chemical composition.

The changes that took place in both explanations about Chemistry and in the language of Chemistry, together with the fact that they were finally recognized as a revolution, both by its protagonists and by later authors, have led later historians of science such as Thomas S. Kuhn, to claim that the "chemical revolution is a paradigmatic example of a scientific revolution" (1962: 150). According to the mainstream interpretation, this "revolution" consisted in the abandonment of the phlogiston theory and its replacement by a theory of combustion based on the action of oxygen. The development of pneumatic Chemistry, which led to the isolation of several gases and to the study of their chemical reactions, together with the introduction of quantification in Chemistry, with the systematic use of the scales and the law of conservation of mass were, according to this interpretation, the main causes of this crisis. This widespread image of the chemical revolution has been discussed by several authors who have toned down the revolutionary character of the changes that had taken place during those years, and have shown the existence of a rich tradition of chemical research throughout the 18th century, which was not focused on the problems traditionally associated with the chemical revolution.

Phlogiston theory, however, presented an important problem, as I have already mentioned, with regards to the weight of the substances that participated in combustions. This was Lavoisier's decisive argument: how to explain the long-known fact that the residues of combustion weighed more that the original metal? Some authors proposed the *ad hoc* hypothesis of the negative weight of phlogiston. But this was *illogical* for Lavoisier, who around 1772 started to elaborate and defend in his *Mémoires* presented to the *Académie des Sciences* the idea that this increase in weight was due to the fixation of a part of the *élan vital* in the metal, so that the fire matter or caloric was released and the corresponding calix was formed. Lavoisier called this part of the *élan vital* "acidifying principle" and later "oxygen principle", since he considered it the principle that conferred on substances their acid character. After the discovery of acid that did not contain oxygen, mainly with the electrochemical experiments of Humphry Davy

(1778-1829), Lavoisier's ideas were questioned, *but the term "oxygen" has remained in use to date*.

Against the background of this chemical revolution the *Méthode de la nomenclature chimique* (1787) was published. Its point of departure was the new concept of chemical composition consolidated during the 18th century. The point of departure of the new nomenclature was the list of simple substances elaborated by Lavoisier taking as a point of departure the well-known definition that proposed to "consider as simple every substance that couldn't be decomposed" (1789 p. 7). Pretending to have eliminated phlogiston from the face of Chemistry, metals became simple substances and calixes substances composed by a metal and oxygen. Nevertheless, some substances such as calix and magnesium (compound substances), appeared on the famous list of thirty three simple substances in Lavoisier's *Traité élémentaire de chimie* (1789), since they had not been analyzed so far.

The list also included some "radicals" such as "muriatic radical", "fluoric radical" or "boracic radical", since for Lavoisier the corresponding acids were not simple substances but rather formed by these radicals plus oxygen, in spite of the fact that it had been impossible to analyze.

The distinction between simple and compound substances made it possible to establish clearly different names for both types of substances. In *Méthode de la nomenclature chimique* simple substances are designated with a single name, without much consideration of the criterion employed to coin such term. On the list of elements proposed by Lavoisier we find terms formed according to the chemical properties of the element (oxygen, hydrogen), others derived from the name of the mineral they came from (tungsten), and even names taken from the alchemical tradition (mercury). The authors of the *Méthode* disregarded the names of the elements which, in general, had been in use until then.

The opposite happened with the terms used to designate compound substances whose number was, already at that time, far larger than that of simple substances. Compound substances were designated by means of binary names, in which the roots of the names of the elements were used to indicate their chemical composition. Hence a substance that had been until then designated with names such as "vitriolic tartar", "duplicated archane", or "Glaser sal polychrest" became "sulfate of potassa", a term that refers to the substances that come into its composition. This method led not only to the elimination of multiple synonyms employed to name a single substance but also to the establishment of a single criterion, chemical composition, to name compound substances.

Another problem that the authors of the *Méthode* had to solve was the terms employed to designate compound substances with identical elements albeit in different proportions. In this case, the use of expressions which indicated only the elements of the compound was not appropriate, since the same name could conceal the fact that the denoted substances had very different properties. For instance, the use of the expression "copper oxide", in which only the chemical composition of the compound is mentioned, is confusing, since it can be applied both to a red solid and to a black oxidant powder. In order to solve this problem, the authors of the new nomenclature introduced several prefixes and suffixes that provided information about the proportion in which those elements were present in the compound.

The *Méthode* was received in different ways by the different groups interested in Chemistry in European countries. For instance Priestley, who would never accept Lavoisier's ideas on combustion, also rejected most of these new terms, considering that they were based on principles that had not been sufficiently established (Berthelot 1890). However, in most cases the new nomenclature was accepted, even by those chemists who did not fully subscribe to Lavoisier's new ideas on combustion. Some of these authors proposed variations: for instance, the term "azote" was rejected and in its place the present denomination, 'nitrogen' was proposed. It is worth mentioning that the translator of the text of the four French chemists did not follow steadily Lavoisier's recommendations; the most striking case was that of his German translators, who decided to German roots (instead of Greek, as the authors of the nomenclature recommended), and coined terms such as 'Sauerstoff' or 'Wasserstoff', which have similar meanings to 'oxygen' and 'hydrogen' respectively.

In spite of diverse modifications, the ideas of the *Méthode* were enormously influential on later Chemistry, most particularly on inorganic Chemistry. The use of roots that design the elements of the compound and different suffixes and prefixes that inform about the relative proportion of those elements is still the basis of a large part of the terminology of inorganic Chemistry. Lavoisier's nomenclature also contained a system of symbols designed by Jean Henri Hassenfratz (1755-1827) and Pierre Auguste Adet (1763-1834). However, and due among other things to the typographical difficulties of reproducing these symbols in books, its diffusion was quite limited. At the beginning of the 19th century, the new notation introduced by Jacob Berzelius, very similar to the modern chemical formulae, overthrew Hassenfratz and Adet's proposal.

If we follow the series of works by Lavoisier in all the *Mémoires* presented to the *Académie des Sciences*, it is possible to witness almost step by step the creation of modern Chemistry, albeit with terms from the old tradition, that of phlogiston and pneumatic Chemistry, to which Lavoisier belonged. I do not witness, however, any problems of incommunicability, untranslatability, incomparability, or unintelligibility[7]. Even though we are witnessing a conceptual change of enormous proportions both quantitatively and qualitatively, the phenomena described under the notion of semantic incommensurability are non-existent. What, then, led Lavoisier to conceive a project such as a change of language in Chemistry? Figuier (1879) believes that Lavoisier and the other authors of the *Nomenclature*,

> In order to consolidate the foundations of pneumatic theory and to break all ties with the past, the French chemists conceived the project of completely reforming chemical language, and to establish for all compounds a system of nominal designation, according to the theories of the new school.... It is clear that by introducing in the language the new truths, forcing ideas to enter in the soul through the artifice of words, he contributed to the consolidation and propagation of the new Chemistry as powerfully as the discoveries that fixated its evidence. (1879 pp 475-476.).

Thanks, among other things, to the discoveries developed in his *Mémoires*, Lavoisier manages to surround himself with allies; only afterwards does he initiate his task of undermining the old system: *the reformation of language*. For some decades chemists had been complaining about the imperfections of their nomenclature. The names of chemical substances coined throughout the centuries and sanctioned by use, perpetuated to perfection a tradition but transmitted, at times, false ideas. Moreover, the discoveries of new substances in the 19th century demanded the creation of new designations.

Lavoisier, persuaded of the importance of words in the shaping of ideas by his reading of Abbot Étienne de Condillac, used this opportunity to make one of his wishes come true: to break with the past and to be reborn through *dubbing*. The *Méthode* is completed by a "Dictionary" which records the equivalences between the new and old names, insofar as the old names did not conceal "false ideas". We find, for instance, "deflogisticized air" and "flogisticized air"; what we *do not find* in this "Dictionary" is *phlogiston*, not even as an 'imaginary entity' or 'Stahl's hypothetical entity'. It seems that 'phlogiston' was the only term that, for Lavoisier, enclosed false ideas -- or perhaps the explanation for this remarkable absence lies elsewhere. If we look up 'caloric', however, we will find it, and next to its corresponding "old name" we will read the following: "Igneous fluid. Fire. Fire or heat matter": that is to say, the referents of 'phlogiston'. Even though the authors show concern for continuity, keeping the old names that do not conceal "false ideas", the Nomenclature is the key to the transformation of a nascent Chemistry. It is not simply the proposal of a school, of a new chemical theory, it is

> An irreversible rupture from the past: in one generation chemists forget *their natural language consolidated by centuries of use*. The previous texts become illegible and are relegated to an obscure prehistory. A rupture also between academic and craft-like Chemistry… It is the end of the age of the *Encyclopedia*, when a chemist such as Venel could proudly say that 'Chemistry comprises a twofold language, the popular and the scientific one. (Besaude-Vincent, 1989 p. 424, italics added)

It is in the *Traité élémentaire de chemie* of 1789, a summary of his old *Mémoires* presented before the *Académie* and translated into the new nomenclature, where we can observe the relevance of language for science in Lavoisier's opinion. In fact, the revolutionary chemist places his *Traité* under the eminent patronage of a contemporary philosopher, Condillac. A reading of the "Preliminary Discourse" of the *Traité*, raises the distinct possibility that the Chemical Revolution may have been inspired by a philosophy.

If this were so, it would be a highly exceptional case, worthy of our attention. Why would Lavoisier, at the same time as he strives to break with scientific tradition, accept his subjection to a philosopher? The *Traité* is thus presented as a scientific experience that corroborates Condillac's theses.

Lavoisier extracts from Condillac's work (particularly his *Logique*) an interpretation of the situation and a diagnosis of the difficulties faced by Chemistry: the illness is of linguistic origin. False ideas are channeled through words; scientific errors are linguistic errors. Thus Lavoisier finds in Condillac justification for the elaboration of a nomenclature, and reciprocally it does not do Condillac any harm that an eminent scientist of his day sould corroborate his philosophical theses. But along with this, Lavoisier also justifies a disregard for tradition: a negative conception of history as interweaving of errors and prejudices that must be set aside so as to rediscover nature. In his *Traité de la Sensation,* Condillac develops his convictions about the formation of ideas and points to its similarity with the formation of a –chemical— body composed of simple bodies, that is to say, Lavoisier's Chemistry.

The "Preliminary Discourse" (1789) starts by staing that when Lavoisier began to elaborate this *Traité*, he had set out to develop something more than the *Méthode o*f 1787,

> But I understood better in dealing with this text that until then I had not proven the principles established by Abbé Condillac in his *Logic* and in some of his other works. He established that *we do not think but*

> *with the aid of words; that languages are true analytic methods; that the simplest, most exact and adequate algebra in the way of expressing its object, is at the same time a language and an analytic method; in short, that that art of reasoning is no more than a well-made language.* And in fact, while I thought I was only dealing with nomenclature, while my only aim was to perfect the chemical language, I was not aware that the task changed in my hands, and without my will, into an elementary treatise of Chemistry. (1789 p.1-2, italics added)

And so the name of a substance is, in Lavoisier's words, "the faithful mirror of its composition", as the name constitutes the inverted image of the analysis carried out in the laboratory. The nomenclature is more than a lexicon that reflects Lavoisier's laboratory practices: it defines a world trapped between the analysis carried out by the scientist and the catalogue of names collected by the author of the *nomenclator*. This is Lavoisier's feat: a new way of speaking and doing. He creates an *elemental* Chemistry in both senses of the expression: built on the basis of the elements and extremely simple, accessible to children as he says in the "Preliminary Discourse", and, particularly, to anyone who "knows nothing about Chemistry".

However, there remain even in the *Traité* certain ambiguities of Lavoisier's system:

a) Despite attempting to do away with the Chemistry of principles, Lavoisier does not eliminate all the element-principles: do caloric and oxygen not play the role of principles in the proper sense of the word, as universal mediators of all reactions?

b) Even when Lavoisier pretends to renounce the tradition which looked for elements and principles, he does not rule out its terms (he actually does so only in the case of 'phlogiston'). A curious oversight in someone so fastidiously concerned with errors transmitted through language. As we have seen, "element" is the equivalent of "simple body" in Lavoisier's Chemistry.

c) The break with tradition is neither total nor clear. However, in the opinion of many chemists and historians of Chemistry, Lavoisier's revolutionary intention was stronger than his acts. His work poses in History as a revolution. A revolution attributable to a single man, even though it is the labor of a whole generation of chemists, as I have suggested. Shortly before his death in 1792, he writes:

"This theory is not, as I often hear, the theory of French chemists: it is *mine* and this is a property that I claim before my contemporaries and posterity" (quoted in Berthelot, 1890 p. 143, italics added)

d) Shortly before Lavoisier's death, an essential element of his system is attacked, something that should have at the very least caused the word "oxygen" to be abandoned. In 1819, Hamphry Davy, the British chemist who until the end of his days was convinced that Lavoisier had not substituted phlogiston theory, showed that muriatic acid did not contain oxygen (the universal acidifying principle) and isolated chlorine (another acidifying substance that takes part in combustions and calcinations). A capital discovery, since it overthrew oxygen as the universal principle of acidity.

In fact, Lavoisier seemed to attribute to language changes a political rather than a conceptual or theoretical role; in order to institute his Chemistry he resorts to a philosopher, not to science, to find the means for this new institution. If we reform language and we teach it to all those who know nothing about Chemistry, we will soon achieve the obliteration of tradition, historical concealment and perhaps the *material conditions* for incommensurability. The old language did not prevent Lavoisier from conceiving, formulating and propagating his discoveries; neither did it pose any epistemological difficulties whatsoever to other researches who learned Chemistry through Lavoisier's nomenclature. The scientific language that Lavoisier used in order to produce his conceptual changes was the old one, but in order to impose those changes he needed to produce a new nomenclature. What relationship is established here between language and concept? The new concepts were shaped from the old lexicon; the new concepts were reformulated in the new nomenclature. I insist: the *Traité* is nothing other than a summary of the *Mémoires* presented by Lavoisier to the *Académie des Sciences.* There can be conceptual change, therefore, without linguistic change, as Lavoisier's whole oeuvre demonstrates. Of course, 'phlogiston' does not appear in the nomenclature, but 'caloric', 'fire matter', or 'heat matter' do. What do these expressions refer to? Those same ones that 'phlogiston' also denoted, as I have tried to prove. When both referent and reference exist, can there be no concept? Lavoisier had his misgivings about the referent of ‘caloric’, but he bets on its existence. In *Réflexions* we find the following statement:

> I do not deny that the existence of this fluid [he is talking about heat matter] might be, up to a certain point, hypothetical; but even assuming that it is a hypothesis which has not been rigorously proven, it is the only one that *I am obliged to formulate*. The followers of the phlogiston theory are no more advanced than me on this matter, and if the existence of the igneous fluid is in fact a hypothesis, it is a *common hypothesis* to both our systems.” (1783 p.641, square brackets and italics added)

And this is the formulation of *Traité élémentaire de chimie*, six years later:

> These phenomena are hard to conceive without admitting that they are the effect of real and material substance, of a very subtle fluid that comes through the molecules of all bodies, separating them; and even assuming that the existence of this fluid is in fact a hypothesis, it will be shown blow that it explains natural phenomena in a very felicitous way ... In consequence, we have named the cause of heat, the eminently elastic fluid that produces it, with the name of *caloric*.. (1789 p.19)

Lavoisier will explain with great precision why he proposes this new word. It is not because there is a conceptual change; ‘caloric’ does not reflect this kind of change. For Lavoisier, it is a question of stylistics:

> This was what led me, in the *Mémoire* I published in 1777, to design it with the name of igneous fluid and heat matter. Later, in the work we

> wrote in collaboration Morveau, Berthollet, and Fourcroy on the reformation of chemical language, we believed these periphrases that lengthen discourse, make it tiresome, less precise, less clear, and even frequently do not imply sufficiently clear ideas. In consequence, we have designed the cause of heat, the eminently elastic fluid that produces it, with the name of caloric. (1789 p.19)

A linguistic change does not necessarily imply a conceptual change, and nor does a conceptual change necessarily imply a linguistic change.

5. Conclusion: presence, existence, reference.

If a substance is present in an object, that substance exists. From the contrary fact that a substance is not present in an object it is not inferred, however, that this substance does not exist elsewhere or in a different form. Keeping in mind this platitude was very useful for my reading Lavoisier's texts against the phlogiston theory. However, and despite its transparency, this idea is often disregarded. In general, from the existence of something, its sensorial or observational presence is inferred, but the reciprocal statement is not true, which is the logically correct one; we are so used to the kind of information that the senses provides that, at times, this way of knowing tricks us.

When Lavoisier discovers that phlogiston is not contained in combustible bodies, he rejects the term and all the descriptions associated to the term except one: the primitive description that bound it rigidly to fire matter. He later re-baptizes the same object with the name 'caloric'. Nothing much happens to the initial description or the object to which it was causally bound: fire matter is not found fixed to bodies, it is free but it can and does combine in important proportions with aeriform bodies, in lesser proportions with earthy bodies, and it does not combine with water.

If fire matter could cause the designation of 'phlogiston', it also caused that of 'caloric'. What mediated between both terms? Scientific research and two clear intentions on Lavoisier's part: to continue referring to fire matter, on the one hand, and on the other to eliminate the causal chain of references of his phlogistic contemporaries.

Let us reflect for a moment on this quote from *Mémoire sur la combustion en générale (1777)*:

> Bodies cannot burn but in a small number of kind of air, or rather, there cannot be combustion but in a single kind of air, that which Priestley has denominated *dephlogisticized air* and I will call *pure air*. (1777 p.226)

Priestley may have agreed with Lavoisier on giving the expression 'dephlogisticized air' the name 'pure air'. But he never agreed with Lavoisier's own and innovative idea that "there cannot be combustion except in a single kind of air". It was not a problem of language, of terms: it was a severe theoretical discrepancy, which bore fruit in Hamphry Davy's discovery, several years later, that combustion does not take place exclusively in the *presence* of oxygen: it also takes place in the presence of other substances. Priestley's suspicions and misgivings may have had – they did have-- a theoretical and empirical foundation.

I have interpreted 'caloric' as the linguistic substitute of 'phlogiston', appealing in so doing to the felicitous reference of the term. Lavoisier was convinced of the substantiality, materiality and reality of caloric; however, being also aware that his proposal did not rest on sufficient experimental proof, he wields a logical argument of persuasion: should anyone (other than Lavoisier) be uncertain about the materiality, substantiality and reality of caloric, they should appeal to the idea that it is an *ad-hoc* explanatory hypothesis. Lavoisier does not expect to persuade others about the materiality, substantitality and reality of caloric; he expects, in this *Traité*, to be understood, and to this end he will appeal to the one feature that phlogiston and caloric shared: its (*prima facie)* hypothetical character. From this it can in no way be inferred that Lavoisier himself was uncertain about the substantiality, materiality and reality of caloric. He did have misgivings about its logical (Occam's razor), linguistic and phenomenological nature, but he did not have conceptual, referential or ontological qualms. It is worth quoting Lavoisier's words in full:

> Being this *substance*, whatever it *may be*, the cause of heat, in other words, being the sensation we call heat the effect of *its accumulation*, it cannot be designed in a rigorous language with the name of heat, *because a single denomination cannot express both*

> *cause and effect.* (…). As well as fulfilling our object in the system we have adopted, this expression has still an added *advantage, which is that it can be adapted to all sorts of opinions,* since, rigorously speaking, we are in no way obliged to assume caloric to be a real matter; it suffices for it to be, as will better understood in the light of the following lines, any repulsive cause that separates the molecules of matter, the effects of which can in this way be examined in an abstract and mathematical manner.
>
> Is light a modification of caloric or, rather, is caloric a modification of light**?** *It is impossible to settle this question at the present stage in our knowledge.* The only certainty is that in a system where the rule of *not admitting but facts* and which avoids *as much as possible* assuming anything beyond what these facts show, different names must be used to design provisionally those *things* that produce different *effects*" (1789 p. 19-20; italics added)[8]

Lavoisier goes on to point out the "exact ideas" behind the word 'caloric': the material properties of caloric, *which act on bodies*[9].

Since 1777 Lavoisier talked about caloric, but his main contributions on this topic must be framed within his works on Physics, in collaboration with Laplace, during 1782-1783. Both aimed to measure the exact amount of heat released by combustion. Their publication *Mémoire sur la combustion en générale (1777)* and *sur la chaleur* (1783) opens with some remarks that, according to Berthelot, "have not lost their value even today, after a century of intense investigations in all the branches of physics and Chemistry" (1890 p. 61)

For Lavoisier, heat was a fluid expanded throughout nature, which is found in all bodies, having penetrated them in some measure. It can be combined with them, and in this state of combination it stops acting on the thermometer and it stops communicating from one body to another. This will be Lavoisier's thesis about heat since 1777 and in his last work, *Traité*, he explicitly reproduces it.

In *Mémoire sur la combustion en générale (1777)*, Lavoisier mentions other conceptions of heat and, as usual, he will discuss them. One of these conceptions is that heat is but the result of an internal, non-sensible movement of molecules of matter. To this conception, Lavoisier and Laplace oppose the principle of conservation of live *forces*, according to which heat is considered the live force resulting from the non-sensible movements of the molecules in a body. Their guiding idea, from a chemical point of view, is an idea of Lavoisier's, who gave a leading role to oxygen during combustion, and thought that this gas provides the heat for combustion taking it from its own supply (gas = base gas plus fire matter). The inequality between the amounts of heat released by the same weight of oxygen combined with different bodies is due to the fact that a proportion of heat remained bound to the products of the combination. The authors, says Berthelot, did not know the wider notion according to which the heat released from these combinations "… does not *really pre-exist* each one of the components of the system, considered separately" (1890 p.106, italics added).

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Translation by Cecilia M. de Rennie

[1] NT: Citations of passages from Lavoisier's works refer to the French edition.

[2] Bruno Latour (1987) *Science in Action*. In this text Latour starts to develop his famous thesis which I abbreviate here as "follow the actors".

[3] I have based my exposition of the evolution of the referent of *phlogiston* and other aspects of the revolution in modern Chemistry, on the following texts: Figuier (1881); Berthelot (1890); Lavoisier (1777, 1783, 1783a, 1789) and Bensaude-Vincent (1989). I have also consulted extracts from Duhem (1902); Meyerson (1902) and Metzger (1930, 1932, 1935). With the exception of Bensaude-Vincent, the secondary sources of this text are closer in time to the historical period considered.

[4] Matter was considered to be corpuscular both by Lavoisier and Stahl. The "molecules" of bodies were more or less separated. The fire matter was located in the interstices. The gases, whose molecules were spread apart, were able to contain much more fire matter than solids, whose "molecular" structure was much more compact.

[5] What Lavoisier accuses Macquer of doing is, in my opinion, the opposite of what Lavoisier himself does here.

[6] There are only a small number of works on the language of Chemistry, despite its peculiar characteristics and great importance. I refer the reader to the works of

Maurice Crosland (1962, 1978), *Historical Studies in the Language of Chemistry*. This work, even though it is not usually cited, is of great interest for researchers of the modern chemical revolution and particularly for all those historians and philosophers of science who write about linguistic changes in the history of science.

[7] I am here in the antipodes of Paul Hoynigen-Huene (2008). Not only do I disagree with the general outline of his work but I'm increasingly persuaded that the Chemical Revolution is not a good example to illustrate the incommensurability thesis proposed by Thomas S. Kuhn in any except its methodological elucidation, proposed by this author et al. (2001).

[8] I apologize to the reader for the length of this quotation. Its purpose is methodological: it is not right to do History and Philosophy of Science exclusively on the basis of secondary sources.

[9] Let us suppose that caloric had the characteristics of a theoretical concept for Lavoisier; that is to say, a concept and its respective term attend to the expressive needs of his system. Now, if Lavoisier could intervene experimentally in other material, substantial and real bodies, with that notion Lavoisier surely had experimental and even empirical proof elements *à la* Hacking (1983) with regards to materiality, substantiality and reality of caloric.

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