Studies in History and Philosophy of Science 42 (2011) 436–444

Contents lists available at ScienceDirect

Studies in History and Philosophy of Science

journal homepage: www.elsevier.com/locate/shpsa

Phlogiston, Lavoisier and the purloined referent

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ARTICLE INFO

Article history:
Received 24 August 2009
Received in revised form 21 September 2010
Available online 13 April 2011

Keywords:
Phlogiston
Chemical revolution
Lavoisier
Caloric
Referent

ABSTRACT

In this paper, I challenge the long-established view that the term *phlogiston* fails to refer. After a close examination of the references of *phlogiston* during Lavoisier's Chemical Revolution, I show that it referred throughout to a natural substance, the *matter of fire*. I claim that Lavoisier eliminated the term but not its referent, which he re-named *caloric*, and it is in the historical and cultural context of the Chemical Revolution that Lavoisier's intentions to refer to it must be understood. Even though I offer a brief description of what I understand as reference, this matter will be the subject of a separate investigation based on the case in the history of science developed here. The aim of this paper, therefore, is not to discuss problems that concern Linguistic Philosophy of Science but to establish a historical case that leads to a important qualification of a widely held assumption.

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 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 refers *phlogiston* still does, if not to a substance found in nature or isolated in a laboratory, at least to 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* fail to refer. It is generally accepted that it does not refer to a substance, but it is commonly believed that *phlogiston* refers to 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 what was taken as a natural substance, the *matter of fire*. I claim that Lavoisier eliminated the term but not its referent, which he re-named "caloric", and I show that Lavoisier never had the explicit intention to eliminate the referent of *phlogiston*, but to discard the term, substituting it by a different one. Finally, I attempt to explain this 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.* I subscribe to 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 a continuation of Science by other Means".

Whereas I discuss the language of 18th century Chemistry, I do not deal with the consequences for the Linguistic Philosophy of Science that emerge from this historical case. My aim is to follow the referent of "phlogiston" through four of Lavoisier's best-known works: *Mémoire sur la combustion en générale* (1777), *Réflexions sur le phlogistique* (*1983*), *Traité élementaire de chimie* of 1789, and Lavoisier et al. *Méthode de nomenclature chimique* (1787). I conclude that until 1789 not even the *intension* of the concept of "caloric" varies with regards to that of "phlogiston"—at least from a non-Fregean intensionalism.

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

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doi:10.1016/j.shpsa.2011.02.002

In Section 2 of this work I briefly develop two polarized conceptions of "failure to refer", a very obscure notion for most historical-philosophical investigations of a given period of any scientific practice. In Subsection 2.1. I speculate on what kind of theory of reference might be useful to study certain periods in the history of scientific practices. In Section 3 I discuss an ambiguity I consider to have become consolidated in mainstream philosophical reflection: the ambiguity between the concepts of existence and presence, which has become almost fossilized in philosophical reflection. The case of the history of phlogiston allows me to show that denying the inherent presence of phlogiston in combustible bodies did not entail for Lavoisier the denial of the existence of phlogiston.

Section 4 is devoted to those philosophers of science with strong linguistic leanings, and to the frequent neglect to undertake a thorough study of the very historical cases they use to illustrate their theses on linguistic-theoretical change. Here I focus on *Méthode de nomenclature chimique* (Lavoisier, Guyton de Morveau, Berthollet, & Fourcroy, 1787), frequently neglected by those philosophers, but not by historians of science specialized in 18th century Chemistry. For the sake of facilitating, strengthening and improving the relationship between History and Philosophy of Science, I hope this section might prove useful. In section 5 I outline the conclusions of this research.

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

Finding out which terms—scientific or otherwise—fail to refer is for Eco (1999) an extremely complex business: both felicitous reference and failure to refer must be negotiated: there is no privileged access to the reference of a term or the absence thereof. Causal theories of reference provide a regulative 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 (1999), this regulative idea operates even when we refer to *impossibilia* or inconceivable objects. Since causal theorists of reference have posited that we can refer to objects we would not know how to determine, 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,* which is neither inconceivable nor impossible, nor, alas, does it exist.

In the antipodes, from a representational-physicalist point of departure (Devitt & Sterelny, 1987), a term fails to refer if it has no actual ontological grounds. *Phlogiston* fails to refer because it has no physical existence. The question is: who claims that phlogiston does not exist? Nowadays, everyone, fundamentally and primarily because science has established it as a fact that phlogiston does not exist as a substance. 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 one of my claims here is that this last factor has been neglected. I do not claim that phlogiston (like dinosaurs) once existed and then ceased to exist, because determining what exists and what does not must be found out through a very laborious process of scientific research. We could say that science allows us to speculate about what exists and what, sometimes mistakenly, is *supposed* to exist. This inquiry involves following the journey of the referents, even when they do not end up being physical-existent or existing objects.[2]

What I will affirm with Bach (1999, 2004) is that the notion of reference is essentially pragmatic; that the difference between alluding to something and referring to something must be established; that to achieve this the semantic properties of terms are not sufficient, and finally that reference is not a semantic but rather a cognitive property that relates thoughts and objects of any kind. My assumption is that to refer to something one must be capable of having thoughts about it and that the propositions one attempts to communicate in the course of referring to it are singular with respect to it. Being in a position to have a thought about a particular thing requires being connected to that thing, via perception, memory, communication and education.

Phlogiston could even be considered to be a fictional entity. In "Nonexistence", Salmon (1998) remarks that referring to a fictional entity is not the same as a *reference in a fiction* or a *fictional reference*: a fictional entity is an object in the same sense as an abstract object, hence we can genuinely refer to it. Therefore, only in a narrow-minded realist theory of reference does "phlogiston" fail to refer.

2.1. A Little bit of history

According to Stahl, a particular principle—*phlogiston* or "matter of fire"—was released when combustible bodies were subjected to a pronounced increase in temperature. This matter of fire is emitted in combustion, in the form of flame and heat. Combustible bodies are therefore *inherently 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 therefore combustible bodies formed by the union of one earth or calx and the inflammable principle. Reciprocally, adding phlogiston to a calx would be enough to rebuild the original metal, and this experiment was frequently carried out by Stahl and his contemporaries. 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 a supporter 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. Kirwan, who fiercely fought for the phlogiston theory for some time, 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 characteristics of inflammable air, a new gas which, thanks to Lavoisier, we can identify today as hydrogen. Between 1771 and 1774 Priestley managed to isolate and name "the main gases known today" (Berthelot, 1890, p. 39), including "dephlogisticated air" or oxygen according to Lavoisier's nomenclature; "nitrous air" or nitric oxide as Lavoisier called it, and "dephlogisticated nitrous air". These findings made it possible to abandon the old conception of air as a simple element (together

[2] Bruno Latour (2000) *Science en action*. In this text Latour also starts to develop his famous thesis which can be abbreviated as "follow the actors".

with earth, water and fire), and 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.

Stahl's doctrine is often reduced, even by Lavoisier, to phlogiston theory, even though it is much further-reaching, but Stahl's Chemistry is grounded on a philosophy of matter which, even though it is corpuscular, is opposed to mechanism. According to Bensaude-Vincent (1991), 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, 1991, p. 419, my translation)

The four elements are then not vague principles, mere 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[3]—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 depending on the quantity of *matter of fire combined*.

Even though from 1772 to 1782 Lavoisier conceived a revolutionary project—according to Figuier (1879), Berthelot (1890), Bensaude-Vincent (1991), Beretta (1993)—he did not express himself immediately in those terms; he waited until 1783 for that. His early publications against phlogiston are extremely prudent. In his account of 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 igneous fluid (Lavoisier, 1777, p. 229) 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 all 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[4], 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 matter of fire and was found *inherently in* combustible bodies. If a combustible body combusted, it liberated the matter of fire *it contained*, that is to say, it emitted heat, light and/or flame. For Lavoisier, phlogiston did not exist *inside* 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 matter of fire was *contained* in combustible bodies. He was opposed, then, to the idea of the *presence* of matter of fire *in* combustible bodies. But he also affirmed that in every combustion a new body was fixed, namely the base of *vital air* 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 *vital air* or oxygen, liberating matter of fire, or caloric, or light, or flame, or all of the above.

> . . . every aeriform fluid, all kinds of air, *are the result* of the combination of any body whatsoever, solid or fluid, with the matter of fire 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 matter of fire, 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)

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 *vital air* or oxygen in the bodies, whereas for Stahl the cause of combustion was phlogiston, that is to say, the matter of fire that was one of the constituents of combustible bodies together with other, generally earthy, substances. Lavoisier denies the *presence* of the matter of fire *in* combustible bodies and denies that the cause of all combustion should be phlogiston, *but he does not deny the existence of the matter of fire*, 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 matter of fire 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 matter of fire end up? In order to answer this question, I will concentrate on two of Lavoisier's works: *Mémoire* (1777) and *Réflexions* (1783).

In Lavoisier (1777) we find 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 matter of fire or matter of light is released" (1777 p. 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 *dephlogisticated air* and I shall here name *pure air*." (1777 p. 226)
3. "In all combustion there is destruction or decomposition of the pure air in which combustion takes place, and the 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

[3] The connection between Lavoisier's theory and the phlogiston theory has been noted among others by Siegfried (1989) & Gough (1988).

[4] Partington & McKie (1939) remarked long ago that many Chemists—contemporaries of Lavoisier—who used oxygen to explain the weight-gain in combustion still resorted to phlogiston in order to explain the release of heat and light.

> the bodies he considers combustible. But if one asks the followers of Stahl's doctrine to prove the existence of matter of fire *in* combustible bodies, they necessarily fall into a vicious circle and are forced to answer that combustible bodies contain matter of fire because they burn, and they burn because they contain matter of fire; 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 Crossland (2004) and Berthelot (1890) insist emphatically on this point. The former considers Lavoisier (1783) "a masterpiece of logic", if not of Chemistry. One might pause to reflect on this insistence and wonder if a revolution might be a mere *inversion*, or even if an *inversion* could become a scientific revolution. The first question shows perplexity; indeed, for example, Bensaude-Vincent (1991) 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 matter of fire, phlogiston, *in* metals, sulfur, etc., is therefore no more than a hypothesis, an assumption which, once accepted explains, admittedly, 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 matter of fire 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 "matter of fire, 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 matter of fire or matter 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". Matter of fire is everywhere and it constitutes one of the imponderable matters, the imponderable matter *par excellence*. However, the aeriform state needs matter of fire. Matter of fire is no longer combined with earths but with airs. Every air is for Lavoisier the combination of matter of fire and a body which will form the gas *base*: there is no gas without matter of fire, hence one can hardly consider dephlogisticated air—"pure air", as Lavoisier calls it—an air. For a substance to be aeriform it must be combined with matter of fire or phlogiston (or caloric), hence Lavoisier's belief that Priestley *improperly* named that air "dephlogisticated air", not because of its linguistic and conceptual associations but because *it did not exist*. Hence Lavoisier has no objections to the word "dephlogisticated"; his problem lies with the notion of "air". I insist: according to Lavoisier's theory it is unlikely for an air not to be combined with matter of fire, or phlogiston or caloric.

> Pure air, Priestley's dephlogisticated 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 matter of fire*, in virtue of the property it has of balancing with the bodies that surround it. (1777 p. 231)

This conceptual change in which matter of fire is not fixed but combined, will allow Lavoisier to develop one of his most important contributions: 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 matter of fire:

> These three states do not depend on anything other than the greater or lesser amount of matter of fire 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 heyday of phlogiston theory, however, are not. Most descriptions of phlogiston elaborated in order to save it from *contradiction* and *question begging* disappear in Lavoisier's system, but matter of fire does not. Some of its properties, too few actually, change (for instance, it is not fixed but combined)[5] 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 *vital air* or oxygen the universal cause of combustion.

In this light, the change in intension between the concept of phlogiston proposed by Stahl or Priestley and Lavoisier himself seems obvious; however, I am interested in emphasizing here the permanence of the *referent*, of the scientific expression studied by this group of Chemists in their daily scientific practices throughout the period I am dealing with here. Intensionalist theories of meaning of Fregean influence have affirmed that intension (or sense as Frege called it in 1949) is a component of the meaning of a term that has the function of determining another of its components, reference. In short, they assume that every intensionalism is Fregean. With Katz (2004) I am persuaded that changes in the intension of (at least) scientific terms do not determine, and might note even alter, the reference of these terms: to establish the reference of a term is not the task of semantics. Therefore, reference conceived in semantic terms is vicarious with respect to the act of referring, in other words, to the *intention* sometimes humans may have to refer to objects.[6] The case of Lavoisier is extremely convincing in this sense.

[5] For Lavoisier, the matter of fire, heat and light was found in free state. It could combine with other substances in solid or gas state and produce a third substance to which fire matter affixed. I insist, my argument is that for Lavoisier, fire matter was not inherently contained in combustible solids such as metals.

[6] In Katz's (2004) terms: "Given an autonomous theory of sense, the question of what the relation is between the sense of an expression and its reference is the question of how a linguistic system of independent senses is related to a domain of objects" (p. 13). Katz sensibly refrains from denying senses, but he liberates linguistic systems from the essentialist weight that Fregean theorists attach to them. He turns language into another instrument by means of which we can connect to the world: even though sometimes they collaborate, if the senses fail to determine reference, there is no necessary connection between linguistic systems and objects. The way in which these autonomous senses are linked to concepts –in case they actually were so—is a different kettle of fish.

My conviction about the existence of the referent of "phlogiston" for Lavoisier 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 position is the idea that fire is an imponderable body, and since substances tend to have extension, matter of fire would not be a substance.

For Lavoisier, however, matter of fire was substantial; in *Réflexions* (1783), the substantiality of matter of fire is determined with precision: fire is an element, 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. Matter of fire is a laboratory substance like many others, 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".

It cannot have been easy for this experimentalist chemist to deal with the nature of fire; he was convinced of its substantiality, but he could not prove it experimentally (weighing elements, reactions, residue, etc). Matter of fire had weight but it was not measurable with the instruments available at the time; because of that he invented with Laplace the calorimeter.[7] Lavoisier's conviction was so strong that he chose a curious metaphor to allude to the elemental character of matter of fire, that of water. Fire does not dry, like air; for Lavoisier, fire "soaks", penetrates, invades, fills, saturates.[8]

> 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 the matter of fire (penetrability) will be the Achilles' heel of anti-phlogiston Chemistry, but this won't happen until the mid-1800s. The new name Lavoisier chose to designate matter of fire, "caloric", does not change the *referent* of *phlogiston*; it only changes to some extent the intension of "phlogiston", which can exist in free or combined states and not just in a fixed state as Stahl believed. This change obeys reasons and *intentions* very precisely established by Lavoisier. Below we shall look into exactly 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, 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 *inherent presence of phlogiston in solids*, 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—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 logically a condition of Lavoisier's Chemistry, but the treatment it receives 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 goes on to beg the reader to forget that Stahl's theory ever existed, and follows this request with his own account of the phlogiston theory: it merely 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 being combustible 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 calcinated. If when a body is burnt it releases phlogiston, metals should lose weight instead of gaining it. To overcome this limitation, Stahl's followers posited a huge amount of *ad hoc* descriptions 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 matter of fire, heat and light—alas the single description perfectly observable!—: what is released, emitted, liberated in every combustion. After demolishing all the descriptions that attempted to overcome this 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 of 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 appropriating his own findings to make them work in the phlogiston theory, something unacceptable for the *soi-disant* revolutionary, Lavoisier.

[7] I thank an anonymous referee of *Studies in History and Philosophy of Science* for reminding me of this fact.

[8] Matter was considered to be corpuscular by both 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.

> 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)[9]

Lavoisier's actual criticism, in my opinion, is not only 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 also concerned with the reference of phlogiston, by the determination of its reference; this is something scientists attempt to do. He was convinced of the material existence of *fire* and wanted to offer irrefutable experimental proof of its existence as a material substance; this will become clearer below in the discussion of his best known text, the *Traité* of 1789.

On the basis of Kitcher's (1993) formulation, I claim that on realising that phlogiston theorists had given the term so many modes of reference (senses), Lavoisier changes the term *phlogiston* for "caloric" to refer to the same entity: the matter of fire. The argument against phlogiston theory in *Réflextions* is a logical and linguistic argument. In fact, by the end of this text, Lavoisier spells out once more the four phenomena present in 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 "dephlogisticated 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).

Matter of fire, 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.

Since *phlogiston* could refer to anything, Lavoisier considered it necessary to eliminate and substitute it. Nothing happened, however, to the primeval referent, namely igneous fluid, of *phlogiston*; the matter of fire continues to be studied by pneumatic Chemistry, or the Chemistry of Lavoisier, or modern Chemistry.

4. The role of scientific language for Lavoisier

There are few works on the language of Chemistry, despite its peculiar characteristics and great importance. I refer the reader to the works of Crosland (1962, 2004), *Historical Studies in the Language of Chemistry*, Bensaude-Vincent (1983) *A propos de Méthode de nomenclature chimique*, and Bensaude-Vincent and Abbri (1995) *Lavoisier in European context. Negotiating a new language for Chemistry*. Their works, even though they are not usually cited, are of great interest for researchers of the modern chemical revolution and particularly for philosophers of science who write about linguistic changes in the history of science.

The lexical work of several French Chemists culminated with the publication, in 1787, of *Méthode de nomenclature chimique* (Lavoisier, Fourcroy, Berthollet, & Morveau). It contains a systematic set of rules to name substances based on Lavoisier's ideas, which involved abandoning the theory of phlogiston and consolidating the new ideas on chemical composition.

Its point of departure was the new concept of chemical composition consolidated during the 18th century. With the supposed elimination of phlogiston from the face of Chemistry, metals became simple substances, and calxes substances composed by a metal and oxygen. The authors of the *Méthode* left the names of the elements which had been in use until then almost untouched, but changed those 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. 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.

Following 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[10]. Even though there was 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), Bensaude-Vincent and Abbri (1995), and Bensaude-Vincent (1983, 1991) believe 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. (Figuier, 1879, pp. 475–476)

Thanks 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*. 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 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, "deflogisticated air" and "flogisticated 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

[9] What Lavoisier accuses Macquer of doing is, the opposite of what Lavoisier himself does here.

[10] I am here in the antipodes of Hoyningen-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 respect except its methodological elucidation, proposed by Hoyningen-Huene & Sankey (2001).

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 primeval referent 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. (Bensaude-Vincent, 1991, p. 424, italics added, my translation)

It is in the *Traité* 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 this subjection to a philosopher? The *Traité* is thus presented as a scientific experience that corroborates Condillac's theses.

Lavoisier draws 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 tantamount to 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 should corroborate his philosophical theses. But 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:

> 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 veritable 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 scientific practices and the catalogue of names collected by the author of the *nomenclator*. Here lies 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 and errors 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?[11]
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.
c) The break with tradition is neither total nor clear. However, 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, 1890p. 143, italics added)
d) After 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, Humphry Davy—as Siegfried (1964) remarks—showed that muriatic acid did not contain oxygen 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.

Lavoisier seemed to attribute to language changes a political rather than a conceptual or theoretical role, and from this perspective it is also possible to explain why Lavoisier needed to make the term "phlogiston" disappear. 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 researchers 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? Clearly a pragmatic one, since the new concepts were shaped from the old lexicon; the new concepts were reformulated in the new nomenclature. There can be conceptual change, therefore, without linguistic change, as Lavoisier's whole *oeuvre* demonstrates. Of course, 'phlogiston'—unlike "caloric"—does not appear in the nomenclature. What does caloric refer to? Among other things, to the same primeval referent

[11] Perrin (1973) argues that not just caloric and oxygen, but all the substances that belong to the first group of Lavoisier's table functioned as principles. I thank one of the anonymous referees of *Studies in History and Philosophy of Science* for this indication.

of 'phlogiston', as I have tried to prove. *When both referent and reference exist, can there be no thought*? Obviously, it is possible for the linguistic expression not to exist, but it is impossible for the thought not to exist. Lavoisier had his misgivings about the referent of 'caloric', but he bets on its existence:

> 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 below 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 designate it with the name of igneous fluid and heat matter. Later, in the work we wrote in collaboration with 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 designated 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 entail a conceptual change, and nor does a conceptual change necessarily entail 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 cannot be inferred, however, that this substance does not exist elsewhere or in a different form. Keeping in mind this platitude was very useful in my reading Lavoisier's texts against the phlogiston theory. However, and despite its transparency, this idea is often disregarded. In general, a belief in the existence of something will lead to the assumption of its presence in that same thing or in another one. In my interpretation, the case of phlogiston shows that the observational presence of the igneous principle which led to the attribution of the inherent presence of phlogiston in metals, proved neither the presence nor the existence of phlogiston.

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 to matter of fire. He later re-baptizes the same object with the name 'caloric'. Nothing much happens to the initial description or to the object to which it was causally bound: fire matter exists in free state and its *presence* is detectable exclusively under laboratory conditions: then, it can be a referent.

If matter of fire 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 matter of fire, and to eliminate the "causal chain of references" of his phlogistonian contemporaries.

Let us reflect for a moment on this quote from *Mémoire* (1777):

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

Priestley could have agreed with Lavoisier on giving the expression 'dephlogisticated 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 Humphry Davy's discovery, several years later, that combustion does not take place exclusively in the *presence* of oxygen. Priestley's suspicions and misgivings may have theoretical and empirical foundations.

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 resort to the idea that it is an *ad-hoc* explanatory hypothesis. Lavoisier does not expect to persuade others about the *materiality, substantiality 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 designated 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 substance it suffices for it to be, as it 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 designate provisionally those *things* that produce different *effects*". (1789, pp. 19–20; italics added)[12]

[12] 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.

Lavoisier goes on to point out the "exact ideas" behind the word 'caloric': the material properties of caloric, *which act on bodies*[13].

Since 1777 Lavoisier talked about caloric without naming it, but his main contributions on this topic must be framed within his works on Physics, in collaboration with Laplace, during 1782–1783.

For Lavoisier, heat was a fluid expanded throughout nature, 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, the *Traité*, he explicitly reproduces it.

After my discussion of some problems linked to the language of 18th century Chemistry, I hope to have shown in this paper that the received view that "phlogiston" fails to refer is flawed, since for almost a century "phlogiston" and later its heir, "caloric", referred to what was considered to be a natural substance. In this paper I also attempted to show that for Lavoisier there was an identity between the referent of "phlogiston" and that of "caloric".

Whereas I do not deal with the consequences for the Linguistic Philosophy of Science that could be inferred from this historical case, these consequences deserve a thorough examination, and I intend to discuss them when I develop some more ideas on the notion of reference that I believe might be useful to account for the linguistic problems of scientific practice.

Acknowledgements

This paper is based on Chapter 5 of my doctoral dissertation at Universidad de Buenos Aires later published as Lewowicz (2009). I am particularly thankful to one of the anonymous referees of this journal, whose comments, recommendations and corrections greatly improved this paper. I am indebted to Prof. Roberto Torretti for his attentive reading of my manuscript and his lucid comments. I also thank my translator for her assistance in providing language help, writing assistance and proof-reading the article.

Translation by Cecilia M. de Rennie.

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[13] 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.