



Discussion

On the continuity of reference of the elements: a response to Hendry

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Abstract

Robin Hendry has recently argued that although the term ‘element’ has traditionally been used in two different senses (basic substance and simple substance), there has nonetheless been a continuity of reference. The present article examines this author’s historical and philosophical claims and suggests that he has misdiagnosed the situation in several respects. In particular it is claimed that Hendry’s arguments for the nature of one particular element, oxygen, do not generalize to all elements as he implies. The second main objection is to Hendry’s view that the qua problem can be illuminated by appeal to the intention of scientists.

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1. Introduction

In an interesting recent paper Robin Hendry has defended the view that Lavoisier’s conception of elementhood is essentially the same as that of Mendeleev¹ (Hendry, 2005). As many historians argue, Lavoisier’s conception consisted of elements as simple substances and the rejection of elements as principles or basic substances. Meanwhile that of Mendeleev consisted of a dual view including elements as simple substances but attaching more importance to elements as basic substances when it came to classification

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¹ Hendry’s claim is actually more general, being concerned with the term ‘element’ as specified by Lavoisier, Dalton, Mendeleev and Paneth.

(Paneth, 1962; Bensaude-Vincent, 1986; Scerri, 2000, 2005).² Since this terminology is crucial to the rest of this article it should be explained a little further. A simple substance represents the final stage of chemical analysis or chemical decomposition. It represents a substance that can actually be prepared in the laboratory. An element as a basic substance, however, is more akin to a principle, an abstract bearer of properties that although present within all elements cannot be isolated in the laboratory. It is also the form that an element exists in when combined with one or two other elements to form a compound.

Robin Hendry does not deny the distinction between elements as simple substances and as basic substances but argues that there exists a continuity of reference in the use of the term ‘element’ and that Lavoisier’s elements have the same reference as do Mendeleev’s. In the present article I would like to subject Hendry’s view to a historical and philosophical analysis which I believe will show that he is mistaken in the reasons he gives for believing that there was a continuity of reference in this historical case. In doing so I do not intend to deny the continuity of reference of scientific terms. In fact I am in agreement with the general thesis that many scientific terms retain their reference across scientific revolutions.

My point is that in the case of Lavoisier’s, Dalton’s, Mendeleev’s and Paneth’s ‘elements’, Hendry has not established the continuity of reference that he wishes to uphold. Moreover, I agree with Hendry’s overall position regarding continuity of reference of elements but for quite different reasons than his, as I will discuss. One aspect that I wish to highlight, in particular, is that Hendry has only presented arguments for phlogiston and its eventual transformation into just one of Lavoisier’s elements, namely oxygen. Moreover, Hendry seems to generalize his findings to all elements without providing any justification for this move.

For Hendry it is elements as basic substances that represent the continuity of reference.³ To a modern chemist this is rather counter-intuitive given the prevalence of ‘element’ as simple substance in chemistry since the time of Lavoisier. In fact, for the contemporary chemist it is only in discussing the survival of elements in compounds or how to understand isotopes and allotropes that elements as basic substances need to be invoked.⁴ Even then many contemporary chemists would probably reject the notion of elements as basic substances as doing any explanatory work whatsoever. So if anything it is elements as simple substances that the contemporary chemist would want to claim show a continuity of reference. Of course we are currently engaged in a philosophical analysis and so the views of practising chemists are not paramount. Nevertheless it would seem desirable to relate the present philosophical analysis to current chemical thinking.

The questions dealt with in the present article present a case study in the relationship between a purely analytical approach, which Hendry adopts, and a more historical approach, which Hendry claims to provide but, as it would appear, may fail to substantiate.

Hendry begins his article by briefly sketching the historical sequence of events that he proposes to analyze. He states that Lavoisier explicitly rejected an atomistic understanding of the elements whereas Dalton was ‘less pessimistic and correspondingly more speculative, seeing elements as composed of qualitatively identical atoms’. He then attributes Mendeleev with

² The simple substance/basic substance terminology I am using is due to Paneth (1962).

³ Hendry stated as much, in answer to a question from the audience, at the 2004 PSA meeting in Austin, Texas.

⁴ For an explanation of how isotopes and allotropes require that an element be treated as a basic substance rather than a simple substance, see Scerri (2000, 2003, 2004).

having deepened Dalton's conception by specifying the property—atomic weight—that atoms must share if they are to be atoms of the same element. (Hendry, 2005, p. 32)

We begin with an examination of these claims before moving onto other aspects of Hendry's article.⁵

2. Lavoisier elements and Dalton elements

There is much to say on the relation of Lavoisier's view of the elements with Dalton's view on elements and atoms. Bensaude-Vincent has discussed this issue in detail and has stated that although the two concepts may have co-existed there has been little attempt to reconcile them. Bensaude-Vincent identifies the lack of interest in this question with various factors including Comte's positivistic view, as well as his distaste for conceptual analysis and his influencing other authors to adopt the same attitude (Bensaude-Vincent, 1981). Meanwhile, Hendry appears to move effortlessly between Lavoisier's elements and Dalton's elements with no discussion whatsoever on whether continuity of reference existed.

I believe this to be a rather critical omission since Dalton's atomic weights provide what turned out to be the crucial link between Lavoisier's and Mendeleev's elements, which are the major focus of Hendry's paper. To put it simply, Lavoisier, following many precursors, established the need for the new concept of element as simple substance in the sense of a substance that can be isolated. Dalton gave the atoms of simple substances a clear-cut quantitative measure, namely their atomic weights, whereas the conceptual continuity between the old and new senses of the term, if any, was not discussed by any author at the time.

Hendry's identification of Dalton's atomic realism as denoting a continuity with Lavoisier's simple substances cannot be maintained. In any case, although Dalton himself may have supported the existence of real physical atoms, the same cannot be said for the majority of his contemporary chemists who availed themselves of equivalent weights and even atomic weights but with no commitment to physical atomism. Moreover, with a few exceptions, this agnosticism towards physical atomism survived for about fifty years up until the Karlsruhe meeting of 1860.

3. Dalton elements and Mendeleev elements

Hendry's account regarding Dalton and Mendeleev's views on elements appears to be mistaken for two reasons. As mentioned above, Hendry claims that Mendeleev deepened Dalton's conception of an element, while also specifying that atomic weight should act as the criterion for the identification of atoms of any particular element. Although it is correct to say that Mendeleev deepened the conception of an element it was not Dalton's conception that he deepened.

Hendry's claim seems incorrect since Dalton had already identified the elements according to their atomic weights. A large part of Dalton's contribution to chemistry lay precisely in individuating the different elements according to their atomic weights. What Mendeleev did was to associate atomic weights primarily with the elements as basic sub-

⁵ If the order of topics treated appears ahistorical it is because I am following the order of presentation in Hendry's paper.

stances rather than as simple substances and to recognize that the ordering of the elements was best carried out by following a sequence of increasing atomic weights.

Secondly, there is considerable evidence to show that Mendeleev was rather skeptical of atomistic explanations. For example, even though he famously used atomic weights to order the elements in his pioneering periodic tables, he sometimes preferred the term ‘element weight’.

Furthermore, as Kaji has recently emphasized, Mendeleev’s doctoral thesis *On compounds of alcohol and water*, submitted in 1865, was motivated by his interest in indefinite compounds, whose composition was difficult to reconcile with atomic theory. Atomic theory was based only on compounds showing definite proportions. As Kaji also adds, ‘Mendeleev was always cautious about atomic theory’ (Kaji, 2003, p. 194), and cites Mendeleev further as saying:

In fact, while the atomic theory was strongly supported by the law of definite chemical compounds, it was also challenged by the so-called indefinite compounds. (Mendeleev, 1968, p. 24, cited in Kaji, 2003, p. 198)

Kaji adds that:

Paradoxically, then, it appears that Mendeleev was led to believing that weight is an invariable characteristic of elements and thence to the periodic system, but not by adhering to the concept of atoms, because of the failure of the law of definite proportions. (Ibid.)

This author also emphasizes that even though Mendeleev was wary of atomic theory he insisted on the existence of chemical elements, Mendeleev’s term for elements as basic substances, which he clearly distinguished from what he called simple bodies. A further quotation from Kaji’s paper can be used to illustrate Mendeleev’s simultaneous distrust for the atomic theory while still using atomic weights to characterize the elements:

He [Mendeleev] defined the concept of elements without a notion of atoms, he considered atomic weights to be the fundamental property of the elements, but they were not necessarily based on atomic theory ... (Ibid., p. 200)

Another source that analyzes Mendeleev’s views on the atomic theory is a recent book by the Mendeleev scholar Michael Gordin, who writes:

The theory that one would expect to be the most connected to periodicity was also the one that Mendeleev was most loath to take literally: atomism. Physical atomism—the belief that atoms are discrete physical bodies, which we now take for granted—was heavily contested in chemistry in the nineteenth century, and the periodic law eventually served as one of the strongest arguments in its favor. (Gordin, 2004, p. 24)

But as Gordin correctly concludes, it does not follow that Mendeleev was thinking in terms of physical atomism when he conceived of his periodic system. Gordin further echoes Kaji in pointing to Mendeleev’s concern over the atomic hypothesis:

it does not possess even now a part of that tangible visualizability, that experimental reliability, which has been achieved, for example, by the wave hypothesis [of light],

not even to mention Copernicus's theory, which one can no longer call a hypothesis. (Mendeleev, cited in *ibid.*, p. 25)

And as Gordin further concludes:

In a 1864 lecture Mendeleev argued that since definite compounds pointed towards atomic theory and indefinite compounds (like solutions) pointed away from it, 'one should not seek in chemistry the foundations for the creation of the atomic system'. Even as late as 1903 Mendeleev accepted atomism only as a pedagogically 'superior generalization'. (*Ibid.*, pp. 24–25)

My own search for Mendeleev's views on atomic theory has also revealed the following passages:

There is a simplicity of representation in atoms, but there is no absolute necessity to have recourse to them. The conception of the individuality of the parts of matter exhibited in chemical elements only is necessary and trustworthy. (Mendeleev, 1891, p. 219)

Mendeleev repeatedly argues that the atom should be treated as a convention and not realistically. For example he writes:

One may replace the term atomic weight by elementary weight in order to avoid recourse to the atom, which in any case is purely conventional. (Mendeleev, 1968, p. 694)

The atomic hypothesis seems to me to be useless, if only because it does not lead to any general law and because it is not assured of a solid basis. (*Ibid.*, p. 733)

Hendry is therefore incorrect in claiming that 'Mendeleev deepened Dalton's conception of qualitatively identical atoms by specifying the property of atomic weight as the criterion that they must share' (2005, p. 32).

As the above quotations amply demonstrate, Mendeleev did use atomic weight but not to individuate Dalton's atoms, which he only regarded as useful fictions. I believe that Hendry has been too quick to claim a continuity of reference between Dalton's and Mendeleev's conceptions of elementhood and in assuming that Mendeleev shared Dalton's belief in the existence of physical atoms.

4. Mendeleev elements and Paneth (or IUPAC) elements

Eventually there would be another important change in the concept of element. Whereas for Mendeleev atomic weight was used to individuate the elements as basic substances, the discovery of isotopes at the beginning of the twentieth century would bring about another reconceptualization. Henceforth atomic weight could only refer strictly to elements as simple substances, since isotopes of the same element possessed different atomic weights. In addition, as far as the periodic system was concerned, Paneth realized that atomic number, rather than atomic weight, would have to be used to individuate the elements as basic substances.

Hendry states that by the 1920s the discovery of isotopes demanded 'one last reconceptualization' (*ibid.*), namely the ruling by IUPAC that elements were to be defined by their atomic number. He argues that it would be a mistake to attempt to disambig-

uate the word ‘element’ in order to distinguish between Lavoisier elements, Mendeleev elements and IUPAC elements since it would mask the continuity in the manner in which ‘elements like oxygen have been employed in theorizing about the substance they name’ (ibid.). But this appears as question begging and, as mentioned above, this attention to one very specific element is rather important since Hendry proceeds to slide effortlessly into generalizing his arguments to all elements as the title of his article implies.

While I contend that Mendeleev elements and IUPAC elements do indeed represent a continuity of reference, the case for a continuity with Lavoisier elements is far more difficult to argue for. Hendry claims that both Lavoisier and Mendeleev ‘treated the names of individual elements as names for the components of substances that could survive chemical change’ (ibid.). This is unfortunately not the case for Lavoisier, whose insistence on treating elements predominantly as simple substances left him with no means of explaining how elements survive chemical change. This point has been made in great detail in Paneth’s classic article on the nature of the elements and has been echoed by a number of other authors (Paneth, 1962; Bensaude-Vincent, 1986; Scerri, 2000).

5. The essence of elements

Hendry moves on to discussing the question of the essence of elements more directly. He portrays this question in philosophical terms as an opposition between a Lockean view on one hand, and the contemporary Kripke–Putnam view on the other. The Lockean view regards kind terms as stipulated by descriptions that determine the reference. The Kripke–Putnam view meanwhile holds that a kind term is introduced by ostentation. For Kripke and Putnam, whether something is of the same kind may be established, at least in principle, by comparison with the first ostended sample. Hendry diagnoses the difference between these philosophical views further by saying:

The difference between the Lockean and the Kripkean semantic models comes down to a difference in the intentions⁶ they attribute to the introducers and users of a kind-term. (Hendry, 2005, p. 33)

But if Hendry is correct in invoking intention in this way, Lavoisier’s intention, I suggest, was to do away with elements as basic substances, and not to retain them as Hendry seems to believe.

For example, Lavoisier wrote:

All that can be said upon the number and nature of elements is, in my opinion, confined to discussions entirely of a metaphysical nature . . . if by the term elements, we mean to express those simple and invisible atoms of which matter is composed, it is extremely probable we know nothing at all about them; but if we apply the term elements, or principles of bodies to express our idea of the last point which analysis is capable of reaching we must admit, as elements, all the substances into which we

⁶ The reader will note the spelling of this word. Hendry is not alluding to intension as opposed to extension.

are capable by any means, to reduce bodies by decomposition. (Lavoisier, 1790, p. xxiv)⁷

After citing this famous passage Bensaude-Vincent makes the following perceptive remark:⁸

Ici ce décide un changement profond dans les orientations de la chimie: Lavoisier ne condamne pas seulement, les théories des éléments telles qu'elles se présentent, ou se sont présentées, avec défauts et qualités, mais toutes doctrine sur les éléments de la matière. Il jette un interdit sur le concept d'élément lui-même et refoule hors du territoire des sciences. Lavoisier fait alors le pari de remplir un ouvrage de chimie, en laissant un vide sur la question première et fondamentale don't traitent habituellement les chimistes. La chimie n'est pas plus la science des éléments. (Bensaude-Vincent, 1981, p. 77)

Although the notion of simple substances or bodies that are the final point of analysis had been proposed previously to Lavoisier, these suggestions had fallen on deaf ears. Lavoisier changed this situation by giving a definition in the context where it was needed. Again, as Bensaude-Vincent writes, Lavoisier provided a theoretical framework and the appropriate language to ensure that the definition would triumph and that it would be fully effective. The main importance of the *Traité élémentaire* is to develop a theory of composition, sustained by a rational nomenclature and which makes the simple substance into the central concept of the whole of chemistry (Bensaude-Vincent, 1981).

There appears to be little doubt that Lavoisier's revolutionary contribution, and indeed his main intent, was to emphasize the notion of an element as a simple substance. It was not to retain any notion of elements as principles. In addition Bensaude-Vincent writes:⁹

Si l'esprit d'analyse gouverne la chimie, alors le corps simple est au centre de la réflexion; il est pivot de l'édifice. (Ibid., p. 85)

In an earlier passage Bensaude-Vincent explains how Lavoisier did not suppress the term 'element' but redefined it and called it simple 'body'. And yet with this definition Lavoisier claimed a radical novelty in having the ambition to found a completely new chemistry that overthrew the past. Indeed Bensaude-Vincent's next section, which examines Lavoisier's simple body definition more closely, is rather tellingly entitled 'L'intention

⁷ One cannot help but notice the lack of continuity between Lavoisier's anti-atomism and Dalton's subsequent views on atoms. For Hendry these two authors represent another example of the continuity of reference of the term element.

⁸ 'Here a deep profound change in the direction of chemistry is decided upon. Lavoisier condemns not only the theories of elements as they are being presented or were being presented with virtues and vices, but all doctrines on the concept of elements itself and expels them from the domain of science. Lavoisier makes a pact to fill a discourse on chemistry while leaving blank the first and most fundamental question which chemists usually dealt with. Chemistry is no longer the science of elements' (my translation).

Bensaude-Vincent presumably intends the final point, that chemistry is no longer the science of elements, to be taken in the sense of no longer being the science of elements as basic substances. This needs to be stressed in view of the fact that Lavoisier is using the term element in both senses in the quoted passage that she is remarking upon.

⁹ 'If chemistry is governed by the spirit of analysis, then the simple body lies at the center of reflection. It is the pivot of the edifice' (my translation).

révolutionnaire’. And yet Hendry is trying to convince the reader that Lavoisier’s real intention was the preservation of elements as basic substances, or principles, given that his claimed continuity of reference hinges mainly on this point.

6. The qua problem

Another goal of Hendry’s article is to connect his view on the elements with the qua problem which has recently been debated in the philosophical literature (Devitt & Stere-lyny, 1999 ; Stanford & Kitcher, 2000). As Hendry reports, the qua problem has come to be viewed as increasingly problematic for the Kripke–Putnam account of reference. According to Kripke and Putnam, the scientific term ‘water’, for example, involves ostentation of samples of that liquid, which in turn possesses the particular essence of being constituted of H₂O molecules. However, it is not clear qua member of which kind such a sample is being ostended. It could be as a clear liquid, a thirst quenching substance, a liquid in general or any number of other possibilities.

Or as Stanford and Kitcher write:

it is utterly mysterious how, without something more than our causal relation to the sample, we can pick out one, rather than another, of the many kinds the sample instantiates. We are ostending a giraffe or a chunk of gold. However hard we point, we face the problem of fixing the reference of ‘giraffe’ to the giraffes (rather than the mammals, the chordates, the vertebrates, the herbevores, etc.) or of ‘gold’ to gold (rather than to metals or elements). (Stanford & Kitcher, 2000, p. 101)

Investigating the world can only tell us what structural properties objects have. It cannot divulge which ones are of interest in specifying the reference of particular terms. (Ibid., p. 109)

As Hendry states, the general response from philosophers has been to suppose that the K–P view needs to admit some relaxation of its semantic externalism (Stanford & Kitcher, 2000). Hendry disagrees with this consensus and believes that the qua problem is best addressed by invoking

not the theoretical beliefs of the introducers and users of kind terms, but their theoretical interests and explanatory intentions. (Hendry, 2005, p. 35)

Hendry then asks:

What from a theoretical point of view, were they trying to do when they introduced the term? (Ibid.)

His main point is that Lavoisier intended the term element in the sense of something that survives chemical reactions. As I have suggested this was not an intention but a feature that Lavoisier was forced to concede.

7. Was Lavoisier’s definition of an element purely empirical?

Hendry then takes a step back historically to examine Lavoisier’s use of the term ‘element’, and disputes the claim of many authors that Lavoisier defined the term in an operational or empirical sense. Hendry suggests that Lavoisier’s approach consisted more of

‘judging the relative compositional simplicity of reactants and products’ (2005, p. 37). Hendry argues in this manner since he wants to minimize the break that Lavoisier made with the then prevailing view of elements as abstract principles. He therefore questions Lavoisier’s revolutionary definition of an element as the last stage in the decomposition of a compound or at least he argues that Lavoisier’s definition was not entirely empirical. This move towards a non-empirical definition seems to be especially necessary for Hendry in the face of all the apparent evidence pointing to Lavoisier’s break with the classical sense of the term element. But I do not believe that Hendry’s position can be sustained.

Hendry finds support for his move in an obscure historical work by Cessebaum and Kauffmann who prefer to call Lavoisier’s definition ‘analytical’ rather than empirical.¹⁰ Presumably the idea is that a definition which is not purely empirical does not depend on elements as simple substances but maintains reference to elements as basic substances. But as I have already stressed, several times, this was not Lavoisier’s intention. The retention of elements as basic substances was rather a remnant of the pre-revolutionary chemistry that Lavoisier could not initially shake-off as the vast majority of historians seem to concur.

Moreover, a mere broadening of the definition of elementhood that Hendry supports does not really help his project. What Hendry would need to argue is that Lavoisier’s definition which emphasizes basic substances was the overriding one, if he is to argue successfully for his historical thesis that there is a continuity of reference of elements as basic substances.¹¹

8. Oxygen and caloric

Whereas Hendry disagrees with the vast majority of historians who consider that Lavoisier’s definition of an element was empirical, he is quite willing to align himself with the same historians in holding that Lavoisier’s criterion for the simplicity of an element seems to conflict with two of his other theoretical commitments regarding his views on the gaseous state and his theory of acids (Siegfried & Dobbs, 1968; Perrin, 1973; Siegfried, 1982). Hendry reminds us that in discussing the gaseous state of matter, Lavoisier invokes the quantity of caloric that may have penetrated the body in question. Similarly, Lavoisier explains the elasticity of gases by appealing to caloric. Hendry states that for Lavoisier combustion involves the chemical decomposition of oxygen gas into the oxygen principle. Hendry claims that caloric is therefore as much an element as oxygen is, and that this is the reason why it heads the list of simple substances.

There follows a rather odd statement by Hendry:

This allows Lavoisier to distinguish oxygen the principle (simple substance) which may combine with many different simple substances, and must therefore be regarded as capable of surviving chemical change . . . While oxygen the element is a component of water, oxygen the gas is not. (Hendry, 2005, pp. 39–40)

¹⁰ Analytical is being used in the sense of chemical analysis and not in the philosophical sense, which means quite the opposite, namely without resorting to matters of fact.

¹¹ Hendry’s case might have been more convincing if he had argued for the continuity of reference in both senses of the term ‘element’. Unfortunately he does not do so but seems to want to establish continuity only in the sense of element as a basic substance.

The parenthetical inclusion of ‘simple substance’ as a means of qualifying oxygen the principle appears to be a mistake. Simple substances are not principles but quite the opposite, as has been stressed throughout the present article. The two notions are altogether distinct, even for Lavoisier and not synonymous as Hendry appears to imply at this point. But there is a more important reason as to why such subtle points about the role of caloric in Lavoisier’s chemistry may be irrelevant to the overarching question of the continuity of reference of the term ‘element’. It is simply that caloric was very soon abandoned by the chemical community and did not appear in any subsequent tables of elements.¹² I take it that it is permissible to adopt a somewhat Whiggish approach of looking ahead historically, when trying to assess whether a scientific term shows continuity of reference or not. Caloric ceased to refer and is therefore not even a candidate in posing the question of the continuity of reference.¹³

Hendry makes much of Lavoisier’s interpretation of oxygen as the heating principle. However, Siegfried, who Hendry quotes approvingly in other contexts, has written perceptively about Lavoisier’s inclusion of oxygen among the ‘*éléments qui appartiennent aux trois règnes*’. According to Siegfried, oxygen treated as the heating principle is an example of the ‘*taxonomic garbage so to speak*’ (Siegfried, 1982, p. 37). Elsewhere in the same paper Siegfried refers to these elements as ‘*Lavoisier’s list of left-overs*’ (ibid., p. 44). It would therefore seem that undue attention to these elements over the question of the continuity of reference is rather unwarranted. Why, it might be asked, should we go ploughing through the ‘garbage’ to make a point about all the other legitimate elements that were not discarded?

9. Lavoisier’s theory of acidity and the role of oxygen

The second theoretical commitment of Lavoisier’s, which Hendry regards as conflicting with his (Lavoisier’s) criterion of simplicity of elements, concerns the nature of acids. Once again Hendry is in good company in making this claim. But my interest here lies in questioning the use that Hendry puts this issue to, in arguing for the continuity of reference of elements as basic substances (Siegfried & Dobbs, 1968; Perrin, 1973).

As many authors have argued, it is very plausible that Lavoisier regarded oxygen as the principle of acidity. It follows that Lavoisier does indeed envisage a dual role for oxygen, in terms of its being a principle as well as a simple substance, with the latter meaning a substance that may be isolated. Hendry’s way of expressing the situation, and indeed the central argument in his entire presentation, is as follows:

So under what conception does he consider oxygen to be an element? Oxygen (the element) names the component of compound substances (*inter alia*, the acids, water and metallic oxides) that can survive changes in its state of chemical combination, and whose presence in compound substances explains the properties of those substances. In short, oxygen is very much a principle . . . and so falls under the concept

¹² None of the lists of elements published by chemists in the years following Lavoisier’s original list of thirty-three simple substances included caloric. These include the lists by Gmelin, Berzelius and Dalton.

¹³ Ironically, many authors have made precisely this argument regarding caloric and oxygen in the philosophy of science. Caloric may have ceased to refer but its role has been assumed by oxygen. But this is a different point from whether or not caloric as caloric continued to refer.

of chemical element that is present in both older and more recent chemistry. (Hendry, 2005, p. 42)

But at this point Hendry departs from the views of Siegfried and Dobbs in implying that Lavoisier wanted to provide an explanation of chemical composition and so needed to retain the notion of elements as principles. By contrast, as Hendry informs us, Siegfried and Dobbs regard the continued use of elements as principles by Lavoisier as nothing more than an alchemical hangover. Hendry rejects the latter view since according to him Lavoisier intentionally maintained that elements were principles. However, there is no historical evidence for believing that Lavoisier intended to retain the notion of elements as basic substances. On the contrary, Lavoisier intended to rid chemistry of any connection with the older sense of ‘elements’ that he considered as an impediment to the development of chemistry.

But the fact remains that Lavoisier wanted to revolutionize chemistry by focusing on simple substances. His table of elements soon jettisoned *lumière* and *caloric*. Also, the elements that had not yet been isolated, such as fluorine, were eventually isolated as Lavoisier suspected they would be. Later tables, particularly those devised by successive chemists, really did deal with elements exclusively as simple substances that had been isolated, in keeping with Lavoisier’s revolutionary initiative.

Admittedly, the presentation in Lavoisier’s *Traité* may suggest some equivocation on the part of its author. Whereas Lavoisier first announces his wish to center chemistry around elements as simple substances he proceeds to spend the following four chapters in reverting to elements as basic substances. It is only in Chapter 5 that Lavoisier resumes his main intention of discussing elements in a new manner, namely as the final stages of chemical decomposition. One may well accept these facts but without needing to accept that this has any bearing on the continuity of reference of elements in general.

But let me briefly return to oxygen, which is but one element out of the presently known 116 or so chemical elements. Even if one accepts that oxygen played many roles in Lavoisier’s chemistry, including a dual role of element as principle and element as simple substance, this does not imply that the remaining 115 or so elements also show a similar continuity of reference. Hendry has not provided any argument to suggest that the remaining 115 elements show continuity of reference regarding their status as principles or basic substances which, as the reader will recall, is what Hendry is arguing for.¹⁴

Finally, Hendry seems to overlook the fact that Lavoisier made a point of not treating all the substances in his list of elements on an equal footing. Five of the substances, which head the list, are classed as ‘*éléments qui appartiennent aux trois règnes*’. One should perhaps not be entirely surprised if these elements adhere to different criteria of elementhood, thus implying no contradiction with the criterion of genuine simplicity that Lavoisier applies to the majority of his elements. In fact, twenty-three of the original list of thirty-three were simple in Lavoisier’s empirical sense of not being further decomposable. Of the ten anomalous substances, a further eight later became simple in the empirical

¹⁴ In any case, even the dual role of one element, oxygen, that Hendry has rather arbitrarily decided to focus upon, may be irrelevant given that within a few years Humphrey Davy had refuted Lavoisier’s notion that all acids contain the principle of oxygen.

sense. It was not long before chemists compiled lists of elements which were all simple in the empirical sense of Lavoisier, once the chemical revolution had progressed a little further and more difficult elemental isolations had been carried out. For example, Berzelius's list of forty-nine elements, published in 1828, contains none of the anomalous elements which did not comply with Lavoisier's criterion for simple substances. Berzelius's list of elements are all simple substances in Lavoisier's strict sense of the final stage of decomposition.¹⁵ Why should one confine one's attention to Lavoisier's first table rather than his later ones? And indeed why should one confine one's attention to Lavoisier's tables rather than those of later chemists like Berzelius if one is trying to trace the continuity of reference of the term 'element'? In order to establish effectively a continuity of reference in the manner that he has chosen, Hendry would need to examine the views of many other chemists than just Lavoisier, Dalton, Mendeleev and Paneth as he has done briefly, and to my mind inaccurately in several respects.

10. Composition and constitution

Hendry seems to believe that Lavoisier's talk of composition implies a commitment to elements as basic substances. However, as Siegfried has argued, composition is discussed by Lavoisier in terms of simple substances and not in terms of basic substances:

Lavoisier's *Traité élémentaire de la chimie* of 1789 effectively introduced the concept of a chemical element or simple body as any substance not yet shown to be compound. In the twenty years that followed, this concept gained wide-spread, if often reluctant, acceptance, for in spite of its metaphysical uncertainties it provided a basis for the organization of the growing body of chemical knowledge through a systematic nomenclature based on elemental composition. (Siegfried, 1982, p. 29; emphasis added)

Similarly, Bensaude-Vincent makes a subtle distinction between Lavoisier's discussion of constitution, which is carried out in terms of elements as basic substances, while discussion of composition is carried out with reference to elements as simple substances. Again, composition goes hand-in-hand with simple substances and not with basic substances as Hendry would have us believe.

If anything, Hendry should be seeking to establish continuity of reference in both the senses of 'element', as basic substance and simple substance. Instead, Hendry has opted for basic substance and begins his account somewhat paradoxically with Lavoisier who sought to banish precisely this sense of the term element. Likewise, Hendry latches onto Lavoisier's view on oxygen and the other elements of the 'trois règnes'. Many elements were discovered in the subsequent twenty years after the publication of the *Traité* and their discovery renders the 'three realm elements' even more insignificant in deducing general notions of elementhood.

Lavoisier's oxygen theory, that Hendry draws heavily on, was soon refuted by Davy. Neither the elements of the 'trois règnes' nor Hendry's oxygen theory showed any persistence as chemistry developed. These facts alone would seem to weigh against

¹⁵ Similarly, the sixty-one substances in Gmelin's list, published in 1865, are all simple by Lavoisier's empirical criterion.

their use in a thesis which attempts to establish the continuity of reference of the term ‘element’.

11. Conclusions

I agree that there is continuity in the reference of the term ‘element’ across different epochs of the recent history of chemistry. In order to establish the continuity one could argue that the element as basic substance underlies the element as simple substance and so co-exists with each sample of element as simple substance. To put this claim in different words would be to say that every sample of an element as a simple substance is necessarily co-extensive with the element as a basic substance.

When Lavoisier was referring to an element such as sulfur as a simple substance he was therefore also referring to sulfur as a basic substance since the two forms coexist within any given sample.¹⁶ On the other hand, Hendry’s attempt to argue for the continuity of reference in a historical manner is fraught with difficulties in that the historical events point, if anything, to discontinuity.

Hendry’s attempted resolution of the qua problem does not appear to go through. If the resolution is to do with intention, then it is a historical fact that Lavoisier’s intention was to banish elements as basic substances and not to uphold their role in chemistry. The fact that Lavoisier may have failed to banish elements as basic substances altogether, as Hendry reminds us, does not change this fact about his intentions. In addition the appeal to intention of scientists raises new problems as to how one might obtain such information since intentions are not always made explicit. The intentions of a scientist hardly seem like a secure basis upon which to resolve the qua problem or any other problem for that matter.

It may well be that a chemist intends some particular aspect of a transparent liquid to count above all other aspects but intentions cannot be objectively communicated. The Kripke–Putnam account of reference augmented with intentions as Hendry suggests does not therefore appear to be a very promising project, at least not to the present author.

On the other hand, if Hendry’s project boils down to discovering what intention Lavoisier should have adopted then I suggest that the exercise collapses into a blatant form of Whiggism. Perhaps Hendry believes that Lavoisier should have been referring to ‘element’ as basic substance because it is this sense of element that became the bearer of atomic weight for Mendeleev and which was eventually to become the bearer of atomic number in the modern era. Either one should consult the history of chemistry as Hendry seems to recommend, or else one could give a Whiggish reading to the historical events so that it appears as though the likes of Lavoisier, Dalton, Mendeleev and Paneth were all referring to the same ‘element’ as a basic substance. It would seem that Hendry has merely sampled the history of chemistry in order to assert his own belief that there is indeed a continuity in the use of the term ‘element’ among these chemists rather than providing any conclusive arguments for this thesis.

¹⁶ This point, if true, invites the further question of whether elements as basic substance exist in spacetime, although this is not a question that will be entertained in the present article.

Nevertheless, I do not doubt that there is in fact a continuity of reference in the case of the term ‘element’, although whether this can be established by recourse to the historical facts remains an open question.

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