Penultimate draft — Please cite the published version, which appears in Otávio Bueno, Ruey-Lin Chen, and Melinda Bonnie Fagan (Eds.). (2018). *Individuation, Process, and Scientific Practices*, (pp. 259-278). Oxford University Press, New York. DOI:10.1093/oso/9780190636814.003.0012

Retail Realism, the Individuation of Theoretical Entities, and the Case of the Muriatic Radical

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Abstract: Retail realists advocate abandoning wholesale arguments, which concern the reality of theoretical entities in general, and embracing retail arguments, which concern the reality of particular kinds of theoretical entities. They can thus be realists about some and anti-realists about others. But realism about a kind of entity can take different forms depending on how retail realists individuate kinds of entities. This chapter introduces the notion of the inclusiveness of individuation: the more inclusively we individuate a kind of entity, the more theories there are in which it appears. The form of realism that retail realists accept regarding a particular kind of entity can be more selective or more encompassing depending on how inclusively they individuate that kind of entity. This chapter illustrates these ideas in terms of a case from the history of chemistry involving the hypothetical component of hydrochloric acid known as the muriatic radical.

Keywords: scientific realism; individuation; history of chemistry; chlorine; hydrochloric acid; Carl Wilhelm Scheele; Antoine Lavoisier; Humphry Davy; Jöns Jacob Berzelius

1 Introduction

The scientific realism debate concerns, among other things, the existence of theoretical entities. Examples of such entities include the atom, phlogiston, caloric, and the electron. When it comes to the existence of such entities, Magnus and Callender (2004) have advocated a position known as retail realism. According to that position, we shouldn't attempt to resolve this issue by appealing to wholesale arguments, which are arguments about the existence of theoretical entities in general. Instead, we ought to appeal to retail arguments, which are arguments about the existence of particular kinds of theoretical entities. In that case, retail realists can be realists about some kinds of entities and anti-realists about others. But since realism about a kind of entity can take different forms depending on how one individuates kinds of entities, it's important for retail realists to have something to say about how to do so. I take retail realism to be a promising position, and since it is underdeveloped in this regard, my goal in this chapter is to develop it further by providing some ways in which retail realists can individuate kinds of theoretical entities.

In order to meet that goal, I proceed as follows. In section 2, I introduce retail realism in more detail. In section 3, I introduce the notion of the inclusiveness of individuation. In short, the more inclusively we individuate a kind of entity, the more theories there are in which it appears. In order to demonstrate that this notion bears on actual science, I apply it to a case from the history of chemistry. In section 4, I discuss the details of that case, which involves the hypothetical component of hydrochloric acid known as the muriatic radical. In section 5, I use the case of the muriatic radical to distinguish two forms of realism: a more selective kind, which requires individuating kinds of entities less inclusively; and a more encompassing kind, which does not. In section 6, I argue that the muriatic radical should be individuated in a less inclusive way because doing so allows us to adopt a more selective form of realism. Finally, in section 7, I use the case of the muriatic radical to show how individuating kinds of entities less inclusively also allows for a more encompassing form of realism. The upshot of my arguments in this chapter is that, when retail realists claim to be realists about a kind of entity, they ought to be clear about how inclusively they individuate that kind of entity.

2 Retail Realism

In the recent history of the scientific realism debate, the two most influential arguments have been the no-miracles argument (NMA), which purports to support realism, and the pessimistic meta-induction (PMI), which purports to support anti-realism. According to NMA, the explanatory and predictive success of our best theories in the mature sciences would be miraculous if those theories weren't at least approximately true. In contrast, PMI draws upon the successful-but-false theories of the past as a basis for inferring inductively that our current theories are false as well. The realism debate has been going on for some time now, and the participants in the debate continue to disagree about how it should be resolved.

A number of philosophers have argued that it would be unwise to wait for a resolution, and that the realism debate actually requires a dissolution. Among them are Magnus and Callender (2004), who consider what realism might consist in if we were to dissolve the realism debate.[1] Their efforts to do so involve what they call "the wholesale/retail distinction" (2004, 320), which they apply to arguments, positions, and debates.

To begin with, there is the wholesale side of the distinction. NMA and PMI are paradigm cases of what Magnus and Callender call "wholesale arguments," which are "arguments about all or most of the entities posited in our best scientific theories" (2004, 321). Positions like realism and anti-realism can be wholesale as well. "Wholesale realism," for Magnus and Callender, "seeks to explain the success of science in general" (2004, 321), by invoking the existence of the entities posited in our best scientific theories. On the other hand, "wholesale anti-realism seeks to explain the history of science in general" (2004, 321), by showing how we needn't invoke the existence of theoretical entities. Finally, the debate that is conducted in terms of wholesale arguments, and that seeks to determine whether wholesale realism or wholesale anti-realism is correct, is what they call "the wholesale realism debate" (2004, 322). It is this debate that Magnus and Callender want to dissolve.

We can now turn to the retail side of the distinction. Magnus and Callender apply the term 'retail' primarily to arguments, and "retail arguments," for them, are "arguments about specific kinds of things such as neutrinos, for instance" (2004, 321). The arguments that actual scientists put forward regarding the reality of particular kinds of theoretical entities are examples of retail arguments. One of Magnus and Callender's examples of a retail argument consists in Einstein and Smoluchowski's theory of Brownian motion and Perrin's subsequent experiments, which persuaded scientists to accept the reality of atoms (2004, 321, 334).

At this point, we can get clear on what kind of realism survives the dissolution of the wholesale realism debate. Magnus and Callender argue that dissolving the wholesale debate leaves the retail arguments untouched. As they put it, "there may be good reasons to be a realist about neutrinos, an anti-realist about top quarks, and so on" (2004, 333). Moreover, they see the wholesale/retail distinction as providing a "way of distinguishing profitable realism debates from unprofitable ones" (2004, 334). In short, debates conducted in terms of wholesale arguments are unprofitable, while those conducted in terms of retail arguments are profitable. While Magnus and Callender do not use the term 'retail realism' in their paper, other philosophers (e.g., Dicken (2013)) have since adopted the term to refer to Magnus and Callender's position. I'll follow their use, and use 'retail realism' to refer to the position that the wholesale debate ought to be dissolved and exchanged for a number of retail debates concerning the reality of particular kinds of theoretical entities. Retail realism, then, is the realism with which we are left once we dissolve the wholesale debate, and it allows for the possibility of being a realist about some kinds of theoretical entities, and an anti-realist about others.

While Magnus and Callender's paper has not caused the wholesale debate to disappear, it's arguably the case that retail arguments now occupy a more central place in the literature. Even among those philosophers concerned with assessing wholesale positions, many of the arguments they discuss are retail arguments concerning the existence of particular kinds of theoretical entities like the ether and caloric.[2] Moreover, as Dicken (2013) argues, a number of philosophers have defended positions resembling Magnus and Callender's retail realism—according to Dicken, one can find retail realism in the work of Psillos (2009), Saatsi (2010), and Stanford (2006).

I take it that retail realism is a promising position, but that, as it stands, it is underdeveloped. One of my central goals in the remainder of the chapter is to argue that realism about a particular kind of entity can take different forms depending on how one individuates that kind of entity. In that case, when retail realists claim to be realists about a particular kind of entity, they must say something about how they individuate that kind of entity.

3 The Inclusiveness of Individuation

My aim in this section is to introduce the notion of the inclusiveness of individuation. Before introducing this notion, I'll first have to be clearer about the kinds of theoretical entities that I'm concerned with individuating. In order to do so, I'll utilize a distinction that Brading and Landry (2006) draw between the presentation and representation of theoretical entities:

> At the semantic level, . . . theoretical objects, as kinds of physical objects, may be *presented* via the shared structure holding between the theoretical models. However, at the ontological level, a physical theory, insofar as it is successful, must also *represent* particular physical objects and/or phenomena and not merely present kinds of physical objects. (2006, 573)

Their reason for introducing this distinction is "to maintain a level of description in which a physical theory can *talk about* electrons, as theoretical objects, without its having to *be about* electrons, as objects that are physically realized in the world" (2006, 573). In what follows, I'll apply this distinction, not just to theoretical entities drawn from mathematically formalized theories in physics, as Brading and Landry do, but to theoretical entities in general, with the caveat that I'll remain noncommittal about how, exactly, theories present kinds of theoretical entities. More qualitative theories may not present kinds of entities in terms of shared structure, and the important point, for my purposes, is not how they present kinds of entities, but just that they do so.

The notion of the inclusiveness of individuation concerns the presentation of kinds of theoretical entities. Suppose we're examining some collection of theories. If we conclude that all of the theories present the same kind of entity, we've individuated that kind of entity in a very inclusive way. In contrast, if we conclude that only one of those theories presents a particular kind of entity, we haven't individuated that kind of entity in a very inclusive way. In between these two extremes, we can talk about degrees of inclusiveness, and make comparative judgments regarding how inclusively we individuate particular kinds of entities. For example, if we conclude that five theories present the same kind of entity *A*, but only three theories present the same kind of entity *B*, then we've individuated *A* more inclusively than we've individuated *B*.

I intend this notion to be applicable to kinds of theoretical entities that are not themselves individuals. The substances named by mass terms like 'water' are often taken to be paradigm cases of non-individuals (Chauvier 2016, 27-28; Lowe 2016, 51). The central examples of my case study in section 4 are chemical substances, and they all belong to this group. The individuality of other theoretical entities is more controversial. For example, in the philosophy of physics, it's a matter of some debate whether quantum particles like electrons are individuals.[3] It may seem problematic to talk about individuating theoretical entities that are not themselves individuals, especially if one takes individuation to be a sufficient condition for individuality. But the problem here is only apparent. In the lab, scientists can individuate samples of chemical substances, as when chemists distinguish between a sample of water and a sample of hydrochloric acid. Analogously, at the level of presentation, we can individuate kinds of such entities. And even if electrons themselves are not individuals, it's still possible to individuate them qua kinds of entities presented by our theories. More generally, we can individuate the kinds of entities that our theories present, even when it comes to entities that are not themselves individuals.

In section 5, I'll argue that realism about a particular kind of entity can take different forms depending on how inclusively one individuates that kind of entity. That argument will make use of a case from the history of chemistry, and I'll now turn to that case.

4 The Case of the Muriatic Radical

Chemists in the late eighteenth and early nineteenth centuries hypothesized that muriatic acid (now known as hydrochloric acid) contains a substance that they called, among other things, the muriatic radical. I'll begin this section by discussing Scheele's work on muriatic acid in the days before chemists hypothesized the radical. After that, I'll examine Lavoisier's hypothesis of the radical. I'll trace its development through Davy's work on muriatic acid. And finally, I'll discuss Berzelius's views on the radical within the context of his theory of hydracids.

Before doing so, though, it will be necessary to make some remarks about terminology. With the exception of direct quotations, I'll generally use the term 'muriatic acid' to refer to the substance that was variously referred to as hydrochloric acid, acid of salt, and marine acid; and I'll generally use the term 'oxymuriatic acid' to refer to the substance that was variously referred to as chlorine, dephlogisticated acid of salt, and oxygenated muriatic acid. Moreover, I'll often write of the radical of muriatic acid (or 'the radical' for short), even though it's not clear that the chemists I'll discuss were employing the same kind of entity. To be sure, these terminological choices may seem to imply a particular view about how to individuate these kinds of entities. In sections 5, 6, and 7, I'll turn my attention to this issue. For now, though, I'll adopt this terminology simply for the sake of clarity.

4.1 Scheele and the Prehistory of the Muriatic Radical

By the late eighteenth century, chemists had been working with muriatic acid for some time. But oxymuriatic acid was not isolated until Scheele did so in 1774. He isolated it by dissolving impure pyrolusite (manganese dioxide), which he called "manganese," in muriatic acid ([1774] 1931, 20).[4] Scheele called the substance he isolated "dephlogisticated acid of salt" ([1774] 1931, 31). His choice of terminology follows from his phlogiston theory. According to Scheele, only acids rich in phlogiston can dissolve manganese, and they do so by losing their phlogiston, which, in turn, combines with the manganese to effect its dissolution ([1774] 1931, 22). Since muriatic acid can dissolve manganese, Scheele concluded that it must contain phlogiston ([1774] 1931, 28-29). And so, Scheele inferred that the substance that he obtained at the end of the reaction must be a dephlogisticated acid—hence his choice of terminology. For Scheele, then, oxymuriatic acid is a simpler substance than muriatic acid, and one can obtain oxymuriatic acid by extracting the phlogiston from muriatic acid.

Even those, like Berthollet (1788, 276-277), who rejected Scheele's theory acknowledged him as the discoverer of oxymuriatic acid. More recent attributions of the discovery of chlorine to Scheele can be found in the work of early twentieth-century chemists like Lowry (1915, 211). These attributions make some sense in light of the fact that Scheele recognized that he had isolated a hitherto undiscovered substance.[5] However, given the way in which Scheele conceptualized that substance, it's problematic to simply state that he discovered chlorine. Without downplaying the significance of his discovery, we can say that what Scheele really discovered was a way to isolate the substance that later came to be known as chlorine.

4.2 Lavoisier's Oxygen Theory of Acidity

Chemists working in the aftermath of Scheele's discovery went on to hypothesize the muriatic radical as a component of both muriatic acid and oxymuriatic acid. And Lavoisier's oxygen theory of acidity provided the motivation for doing so.

Lavoisier's central claim regarding acids is "that oxygen is an element common to them all, which constitutes their acidity," and that "we must therefore, in every acid, carefully distinguish between the acidifiable base, which Mr de Morveau calls the radical, and the acidifying principle or oxygen" ([1789] 1965, 65). Lavoisier claims that radicals can be either simple substances or compounds ([1789] 1965, 115). And as Le Grand (1972, 11-12) observes, although Lavoisier's critics often took his theory to involve the claim that oxygen is a sufficient condition for acidity, for Lavoisier himself, oxygen is merely a necessary condition.

We can illustrate Lavoisier's theory by means of some of his examples. While acids like phosphoric acid, sulphuric acid, and carbonic acid all contain oxygen, they differ from one another insofar as they contain different radicals, namely, phosphorus, sulphur, and carbon, respectively ([1789] 1965, 60-65). And while sulphurous acid and sulphuric acid contain the same radical, namely, sulphur, they differ in light of the fact that sulphurous acid contains less oxygen than sulphuric acid does ([1789] 1965, 67-68).

Lavoisier was able to show that a number of acids contain oxygen, but he was unable to show that every acid does. Boracic acid, fluoric acid, and muriatic acid proved to be problematic, but Lavoisier is clear that his theory extends to these substances as well. He claims that these acids are each composed of oxygen combined with a hypothetical radical, and indeed, one finds the boracic radical, the fluoric radical, and the muriatic radical in Lavoisier's table of simple substances ([1789] 1965, 175).

Lavoisier hypothesizes the muriatic radical in a particularly striking passage:

> Although we have not yet been able, either to compose or to decompound this acid of sea-salt, we cannot have the smallest doubt that it, like all other acids, is composed by the union of oxygen with an acidifiable base. We have therefore called this unknown substance the *muriatic base*, or *muriatic radical* . . . ([1789] 1965, 71-72)

While Scheele thought he had decomposed muriatic acid by removing its phlogiston, Lavoisier held that no chemist had succeeded in decomposing it, since no one had been able to extract its oxygen. Hence, Lavoisier hypothesized the muriatic radical as that substance which combines with oxygen to form muriatic acid.

Lavoisier and his followers also rejected Scheele's view of oxymuriatic acid. Lavoisier held that this acid is a compound of oxygen and muriatic acid, which he called "oxygenated muriatic acid" ([1789] 1965, 73). But as Le Grand (1974, 214) and Ashbee (2007, 16) emphasize, it was really Berthollet (1788) who took up the challenge of reinterpreting Scheele's results in terms of the oxygen theory, and who thereby did the most to establish Lavoisier's view of the composition of oxymuriatic acid. Importantly, the view of the oxygen theorists is a complete reversal of Scheele's view. While Scheele held that oxymuriatic acid is the simpler substance, for Lavoisier and Berthollet, muriatic acid is the simpler substance. Moreover, the muriatic radical is a component of both acids.

4.3 Davy's Work on the Acids

One of the outstanding problems in chemistry at the time was to decompose muriatic acid and oxymuriatic acid, and isolate the muriatic radical. One chemist who attempted to decompose these substances was Davy, who, for some time, held that muriatic acid is composed of water and "a substance, which as yet has never been procured in an uncombined state," and that "oxymuriatic acid is composed of the same substance, . . . united to oxygene [sic]" (1809, 468).

But in 1810, the year in which his work on the acids culminated, Davy rejected this view. In a paper read in July of that year, he writes:

> in the usual cases where oxygene [sic] is procured from oxymuriatic acid, water is always present, and muriatic acid gas is formed; now, as it is shewn that oxymuriatic acid gas is converted into muriatic acid gas, by combining with hydrogene [sic], it is scarcely possible to avoid the conclusion, that the oxygene [sic] is derived from the decomposition of water, and, consequently, that the idea of the existence of water in muriatic acid gas, is hypothetical, depending upon an assumption which has not yet been proved—the existence of oxygene [sic] in oxymuriatic acid gas. (1810, 236)

As Ashbee (2007, 23) emphasizes, chemists working during this period often misinterpreted their experimental results because they neglected the decomposition of water in their experiments. Davy's achievement in this case was to show that previous conclusions regarding the nature of muriatic acid and oxymuriatic acid did not properly take into account the role of water in various experiments. According to Davy, what happens in these experiments is that oxymuriatic acid combines with the hydrogen of the water to form muriatic acid, leaving oxygen as a byproduct. Since oxymuriatic acid is actually a component of muriatic acid, and since the production of oxygen in various experiments can be traced back to the water, the existence of oxygen in oxymuriatic acid has not been proven. And because of this fact, combined with the fact that the components of muriatic acid are oxymuriatic acid and hydrogen, the existence of water, and of oxygen, in muriatic acid is similarly hypothetical.

In the Bakerian Lecture that he gave in November of 1810, Davy goes on to argue for the view that oxymuriatic acid ought to be considered an element.[6] Davy's argument for the elementary nature of this substance depends on his views regarding the nature of elements. As Siegfried (1964, 119) has observed, Davy's views on this matter owe much to Lavoisier's ([1789] 1965, xxiv) definition of an element as an as-yet-undecompounded body. Davy argues that oxymuriatic acid "has not as yet been decompounded," and is "elementary as far as our knowledge extends" (1811, 1). Golinski (1992, 223) has emphasized that, in making this argument, "Davy brought forward no dramatically new experimental evidence." Davy's point was just that, because existing methods had failed to decompose oxymuriatic acid, it ought to be considered an element. He goes on to push for a change in terminology, on the grounds that 'oxymuriatic acid' is a poor name for "a body which is not known to contain oxygene [sic], and which cannot contain muriatic acid" (1811, 32). He suggests the names 'chlorine' and 'chloric gas' be used instead. Davy is thus credited with showing that muriatic acid is composed of hydrogen and chlorine, and that the latter is an element. And although he saw no reason to reject the term 'muriatic acid' (1811, 33), his work shows why we now refer to that acid as hydrochloric acid.

Interestingly, Davy uses his conclusions in order to argue "that SCHEELE'S view . . . may be considered as an expression of facts" (1810, 237). As Davy characterizes Scheele's view, "the illustrious discoverer of the oxymuriatic acid considered it as muriatic acid freed from hydrogene [sic]; and the common muriatic acid as a compound of hydrogene [sic] and oxymuriatic acid" (1810, 231). Here, Davy is taking advantage of the fact that it was common for phlogiston theorists working in the late eighteenth century to identify phlogiston with inflammable air, which we now call hydrogen.[7] At times, Davy himself engages in some phlogistic speculations and identifies phlogiston with hydrogen.[8] If we identify Scheele's phlogiston with hydrogen, we can see why Davy considers Scheele's view to be correct. However, a number of commentators have noted problems with identifying Scheele's phlogiston with hydrogen (Ashbee 2007, 22, 35; Ladenburg 1900, 19) or with inflammable air (Boantza and Gal 2011, 332-333). Indeed, in later work, Scheele claims that "inflammable Air is composed of heat and phlogiston" ([1777] 1780, 180), which rules out a direct identification of phlogiston with inflammable air. Hence, Scheele's view is only an expression of facts if one mistakenly identifies his phlogiston with hydrogen.

While Davy praises Scheele's view, he also argues that the view of the oxygen theorists "rests . . . upon hypothetical grounds" (1810, 237). If the acidifying principle, namely, oxygen, isn't present in these two acids, then that theory would seem to be in serious trouble. Indeed, a number of commentators have claimed that Davy's work on the composition of muriatic acid and oxymuriatic acid effectively killed off the oxygen theory of acidity (Brooke 1980, 121-123; Chang 2012, 33; Le Grand 1974, 224).[9] Davy also speculates that oxymuriatic acid may be another principle of acidity, and that "on this idea muriatic acid may be considered as having hydrogene [sic] for its basis," i.e., its radical (1810, 243). Davy, of course, recognized that both oxygen and oxymuriatic acid are attracted to the positive surface of a Voltaic battery, while hydrogen is attracted to the negative surface (1810, 241-242). It's probable that this analogy between oxygen and oxymuriatic acid is among his reasons for speculating that oxymuriatic acid is the acidifying principle, leaving hydrogen as the radical. In any case, the point of Davy's speculations was just that there were now good reasons to doubt the central claim of the oxygen theory of acidity, namely, that oxygen is the sole principle of acidity.

4.4 Berzelius on Hydracids

While Davy is now credited with determining the composition of both muriatic acid and oxymuriatic acid, his views did not go unchallenged. One of his most prominent critics was Berzelius, who, for some time, opposed Davy's views regarding these two substances and defended a form of Lavoisier's oxygen theory of acidity.[10] In accordance with that theory, Berzelius held that the components of muriatic acid are oxygen and the "muriatic radicle" (1813, 254). Berzelius presents his own views on muriatic acid and oxymuriatic acid in terms of both atoms (1813, 254) and volumes (1816, 276), and claims that muriatic acid contains one atom/volume of muriatic radical and two atoms/volumes of oxygen, while oxymuriatic acid contains one atom/volume of muriatic radical and three atoms/volumes of oxygen. Regarding the muriatic radical in particular, Berzelius claims that its nature is still unknown, and that chemists have not succeeded in isolating it (1813, 254; 1816, 263).

Berzelius's view of the composition of acids changed as time went on. In 1825, a translation of an appendix from his multi-volume *Lärobok i Kemien* appeared as an article in the *Annals of Philosophy*. In that article, Berzelius advocates the view that there are, in general, two kinds of acids: oxygenous acids and hydracids. The oxygenous acids, for Berzelius, are composed of oxygen and an acidifiable base or radical. Berzelius was therefore in agreement with Lavoisier regarding the nature of these acids. In contrast, a hydracid, for Berzelius, is "a combination of a simple or compound body with hydrogen, which, although destitute of oxygen, possesses all the essential characters of the oxygenous acids" (1825, 180). Berzelius claims that "hydracids must be regarded, therefore, as constituted of hydrogen and a peculiar radical, which, as is the case with the oxygen acids, may be either simple or compound" (1825, 180). Hare (1835) quotes some similar passages from what he calls Berzelius's "treatise of Chemistry" (1835, 61), which was most likely a translation of Berzelius's *Lärobok i Kemien*. In one passage, Berzelius defines hydracids as "those acids which contain an electronegative body, combined with hydrogen," and he claims that "hydracids are divided into those which have a simple radical, and those which have a compound radical" (quoted in Hare 1835, 69). Hare also provides a quotation of Berzelius's definition of a radical, according to which "the combustible body contained in an acid, or in a salifiable base, is called the radical of the acid, or of the base" (quoted in Hare 1835, 69). Importantly, Berzelius does not define the radical of an acid as the non-oxygen part of the acid, and for him, both oxygenous acids and hydracids contain radicals.

One of Berzelius's examples of a hydracid in his 1825 article is muriatic acid, which, by this point, he also calls hydrochloric acid. After distinguishing between "two classes [of hydracids], viz. acids with a *simple*, and acids with a *compound radical*," Berzelius writes: "To the *first* of these classes belong[s] . . . *Hydrochloric acid*; . . . *chlorine* . . . being regarded as [a] simple substance[]" (1825, 181). This passage is significant for at least two reasons. First of all, Berzelius is claiming that hydrochloric acid is a compound of hydrogen and elementary chlorine, and this claim represents a significant departure from the position he advocated in the 1813 and 1816 papers discussed above. Gray, Coates, and Åkesson (2007, 66) observe that Berzelius avoided the topic of oxymuriatic acid between 1817 and 1820, and that by the 1820s, his references to chlorine all suggest that it is a simple substance. However, they claim that Berzelius never explained why he made this change, nor why he abandoned the terms 'muriatic acid' and 'oxymuriatic acid' in favor of 'hydrochloric acid' and 'chlorine', respectively. Moreover, they doubt that Berzelius ever truly converted to the view that chlorine is an element. But it's worth noting that, immediately after the quoted passage, Berzelius goes on to claim that his "principal arguments against the new theory of the constitution of muriatic acid," i.e., Davy's theory, "can no longer be considered as valid," in light of "the analogy between muriatic acid and the hydracids" (1825, 181). Berzelius's appeal to this analogy may go some length toward explaining his use of the new theory and the new terminology. The second reason that this passage is significant is that it shows that, for Berzelius, the radical of hydrochloric acid is chlorine. After all, that substance is the non-hydrogen component of hydrochloric acid, and so, based on the Berzelius's theory of hydracids, chlorine is the radical of hydrochloric acid.

5 Two Forms of Retail Realism

I'll now show how realism about a particular kind of entity can take different forms depending on how inclusively one individuates that kind of entity. It follows that retail realists have to say something about how they individuate the kinds of entities about which they are realists. I'll distinguish between a more selective form and a more encompassing form of realism about a particular kind of entity. And I'll illustrate these different forms of realism by considering two ways of individuating the muriatic radical.

I'll focus my attention on three theories: Lavoisier's oxygen theory of acidity, Davy's new theory regarding the composition of muriatic acid, and Berzelius's theory of hydracids. Lavoisier's theory presents the muriatic radical, or muriatic base, as a hypothetical component of muriatic acid. Davy argued that the components of muriatic acid are in fact hydrogen and chlorine, and he speculated that hydrogen is the basis (or base, in Lavoisier's sense) of muriatic acid. Hence, his theory, combined with his speculations, presents hydrogen as the muriatic radical. Finally, Berzelius's theory presents chlorine as the radical of hydrochloric acid. Each of these theories presents a kind of entity: the radical or basis of what these chemists referred to as muriatic or hydrochloric acid. In short, they present the muriatic radical.

The question at this point is how inclusively we should individuate the muriatic radical. By presenting the muriatic radical, do these three theories all present the same kind of entity, or do they present different kinds of entities? Since inclusiveness is a matter of degree, there are a number of options here. However, in order to illustrate my point, it will suffice to consider the two extreme options, namely, that each theory presents the same kind of entity, and that each theory presents a different kind of entity. I'll label these two options *inclusive individuation* and *exclusive individuation*, respectively.

In light of the fact that Lavoisier, Davy, and Berzelius used similar (though not identical) terminology, we might opt for inclusive individuation. If we do, then the three theories I'm considering all present the same kind of entity: the muriatic radical. In that case, realism about that kind of entity amounts to the claim that these theories also represent the same kind of entity, whatever that might be. Opting for inclusive individuation thus results in an encompassing form of realism about the muriatic radical as it is represented by distinct theories.

Alternatively, one might opt for exclusive individuation. In that case, these three theories present three distinct kinds of entities: Lavoisier's muriatic radical, Davy's basis of muriatic acid, and Berzelius's radical of hydrochloric acid. Exclusive individuation allows for a more selective form of realism about these kinds of entities at the level of representation. There are two ways in which this form of realism can be more selective. First of all, it can amount to a kind of pluralist realism, according to which we distinguish kinds of entities both at the level of presentation and at the level of representation. For example, we might be realists about Davy's basis of muriatic acid, on the grounds that he identifies it with hydrogen. Similarly, we might be realists about Berzelius's radical of hydrochloric acid, on the grounds that he identifies it with chlorine. If so, we have a case in which two theories present two different kinds of entities (Davy's basis and Berzelius's radical) and also represent two different kinds of entities (hydrogen and chlorine). Secondly, after distinguishing kinds of entities at the level of presentation, we can selectively apply both realist and anti-realist attitudes at the level of representation. For example, we might be anti-realists about Lavoisier's radical, on the grounds that his hypothesis regarding the composition of muriatic acid turned out to be false.[11] If so, then unlike Davy's and Berzelius's theories, Lavoisier's theory presents a kind of entity (his radical) without representing it. By allowing for both of these two possibilities, exclusive individuation allows for a much more selective form of realism than the more encompassing form of realism that results from opting for inclusive individuation.

However, as I'll make clear in section 7, exclusive individuation also allows for the more encompassing form of realism, since distinct theories may present different kinds of entities, and yet end up representing the same kind of entity. So while inclusive individuation results in the more encompassing form of realism, exclusive individuation doesn't automatically result in the more selective form of realism, but allows for both forms.

I've illustrated these two forms of realism by considering two options for individuation: inclusive individuation and exclusive individuation. But since inclusiveness is really a matter of degree, the two forms of realism differ from one another in degree, not kind. Realism about a kind of entity is more encompassing when there are more theories that represent that kind of entity. And when we individuate a kind of entity more inclusively, the result is a form of realism that is more encompassing. Realism about a kind of entity is more selective when there are fewer theories that represent that kind of entity. And when we individuate a kind of entity less inclusively, we allow for a form of realism that is more selective.

Since realism about a particular kind of entity can take different forms depending on how inclusively one individuates that kind of entity, retail realists must say something about how they individuate the kinds of entities about which they are realists. In short, my claim is that, just as retail realists have the option to be realists about the neutrino and anti-realists about the top quark, they should have the option to be realists about Berzelius's radical and anti-realists about Lavoisier's radical. But importantly, this latter option requires retail realists to say something about individuation.

While these concerns about individuation are important for retail realists to consider, they may not be all that significant for wholesale realists and anti-realists. Since the arguments they offer focus on theoretical entities in general, the conclusions of those arguments aren't affected much by alternative ways of individuating kinds of entities at the level of presentation. Hence, individuation is a much more pressing issue for retail realists than it is for wholesale realists and anti-realists.

Up until this point, I've argued that individuating kinds of entities more inclusively results in a more encompassing form of realism, while individuating them less inclusively allows for a more selective form of realism. But how should retail realists determine how inclusively to individuate various kinds of entities? In sections 6 and 7, I'll answer this question by considering what retail realists should say about two examples: the muriatic radical and oxymuriatic acid.

6 Example 1: The Muriatic Radical

What should retail realists say about Lavoisier's muriatic radical and Berzelius's radical of hydrochloric acid? Since we're dealing with two theories, we can consider two options. The first is an inclusive individuation of the radical, and a more encompassing form of realism about it.

The second is an exclusive individuation of the two radicals, and a more selective form of realism. I'll argue that the more selective form of realism is preferable to the more encompassing form. And I'll argue that this constitutes a good reason to opt for exclusive individuation and reject inclusive individuation in this case.

Before doing so, I want to clarify my argumentative strategy by responding to an objection. If opting for the more selective form of realism can count as a reason for choosing exclusive individuation, then perhaps a retail realist can adopt the more selective form of realism before taking a stand on the issue of individuation, or even without considering that issue at all. This is contrary to what I argued in section 5. In order to respond to this objection, I'll begin by distinguishing two packages that one must choose between in this case. One consists of an inclusive individuation and the more encompassing form of realism. The other consists of an exclusive individuation and the more selective form of realism. We should consider each of these packages as a whole. If there are good reasons to prefer the more selective form of realism to the more encompassing form, those reasons are ipso facto good reasons to prefer exclusive individuation to inclusive individuation. Hence, I'm not committed to the consequence that retail realists can opt for the more selective form of realism without considering the issue of individuation. On the contrary, they ought to consider the issues of realism and of individuation simultaneously.

At this point, we can consider the combination of exclusive individuation and the more selective form of realism. On that package, Lavoisier's theory and Berzelius's theory present distinct kinds of entities: Lavoisier's muriatic radical and Berzelius's radical of hydrochloric acid, respectively. Distinguishing these kinds of entities at the level of presentation allows for the more selective form of realism at the level of representation. If there are good retail arguments for anti-realism about Lavoisier's radical and for realism about Berzelius's radical, respectively, then we have a good reason to opt for this more selective form of realism, and ipso facto a good reason to opt for exclusive individuation. I'll now argue that there are good retail arguments that support these conclusions.

First of all, Davy's work on muriatic acid supplies us with a good retail argument for anti-realism about Lavoisier's muriatic radical. As we saw in section 4.3, Davy showed that the components of muriatic acid are hydrogen and chlorine. He thereby showed that Lavoisier and the oxygen theorists were wrong to claim that muriatic acid is composed of oxygen and a hypothetical radical. And if there is no oxygen in muriatic acid, Lavoisier's oxygen theory of acidity does not provide any reason to identify one component as the radical over the other. Moreover, both muriatic acid and oxymuriatic acid were supposed to contain Lavoisier's radical as a component substance, and Davy showed that there is no reason to think that these two substances share a component. Hence, the only viable option is to adopt an anti-realist attitude toward Lavoisier's muriatic radical. While Lavoisier's theory presents Lavoisier's radical, it doesn't represent it.

Secondly, Scheele's work on chlorine supplies us with a good retail argument for realism about Berzelius's radical of hydrochloric acid. As we saw in section 4.1, Scheele discovered a way to isolate the substance that later came to be known as chlorine by dissolving what he called "manganese" (really, manganese dioxide) in muriatic acid. He conceptualized this substance within the framework of his phlogiston theory, and referred to it as "dephlogisticated acid of salt." But even if chemists like Lavoisier took issue with Scheele's theory and choice of terminology, they admitted the reality of the substance that he had isolated, and they advanced a number of theories about it. The retail argument for realism about Berzelius's radical, then, is straightforward. Berzelius's radical just is the substance that Scheele isolated in 1774. Since realism about this substance was appropriate in 1774, it was surely appropriate in 1825 when Berzelius identified chlorine as the radical of hydrochloric acid. Hence, we ought to be realists about Berzelius's radical. Berzelius's theory of hydracids both presents and represents Berzelius's radical.

The upshot of these retail arguments is a selective form of realism about Berzelius's radical, but not about Lavoisier's radical. This selective form of realism requires exclusive individuation (they are part of the same package). This form of realism is inconsistent with inclusive individuation, which would result in a choice between an encompassing realism about the muriatic radical as it is presented by these two theories, and a similarly encompassing anti-realism about that kind of entity. The two retail arguments that I've just discussed show that the selective form of realism is preferable to an encompassing realism (or anti-realism) regarding the muriatic radical. Therefore, we have a good reason to prefer exclusive individuation to inclusive individuation in this case.

7 Example 2: Oxymuriatic Acid

What should retail realists say about Scheele's dephlogisticated acid of salt, Lavoisier's oxygenated muriatic acid, the early Berzelius's oxymuriatic acid, and Davy's chlorine? Do the theories of these chemists present distinct kinds of entities or the same kind of entity? And what, if anything, do their theories represent? I'll argue that we ought to individuate the kinds of entities less inclusively in this case, but that we ought to opt for the more encompassing form of realism. By doing so, I'll show how individuating kinds of entities less inclusively also allows for the more encompassing form of realism.

However, I'll start by arguing for a more inclusive individuation of what was known as oxygenated muriatic acid and oxymuriatic acid. More specifically, Lavoisier's oxygen theory of acidity and the theory that Berzelius defended in his 1813 and 1816 papers both present the same kind of entity, which we can call oxymuriatic acid. Both chemists held that oxymuriatic acid is a compound of oxygen and the muriatic radical. Moreover, Berzelius sees himself as defending a more developed version of Lavoisier's oxygen theory. As Berzelius puts it, the contrast is between "the old theory and that of Sir H. Davy," where the old theory is that of Lavoisier and the oxygen theorists; and he goes on to "give [his] reasons for considering the old theory as the most accurate" (1813, 254). The fact that Berzelius sees himself as defending the old theory of Lavoisier gives us a good reason to individuate oxymuriatic acid more inclusively.

The case of Davy's new theory and Scheele's phlogiston theory presents a useful contrast to the Lavoisier-Berzelius case. Davy's theory and Scheele's theory are best thought of as presenting different kinds of entities: chlorine and dephlogisticated acid of salt, respectively. While Davy claims that Scheele's view "may be considered as an expression of facts," he also emphasizes that it is "obscured by terms derived from a vague and unfounded general theory" (1810, 237). Davy does not see himself as presenting a further development of Scheele's phlogiston theory, and he rejects the view that elementary chlorine is a dephlogisticated acid. In that case, Davy's theory and Scheele's theory present different kinds of entities.

When we consider all four theories together, we arrive at the conclusion that, at the level of presentation, there are three distinct kinds of entities here: oxymuriatic acid, chlorine, and dephlogisticated acid of salt. This is because oxymuriatic acid differs from both chlorine and dephlogisticated acid of salt. An oxygenated acid differs both from a phlogisticated acid and an elementary substance. Moreover, it's significant that Lavoisier and Berzelius defended their oxygen theories in opposition to phlogiston theories like Scheele's and Davy's new theory, respectively. Hence, in this case, we have neither an inclusive individuation nor an exclusive one, but instead one that is, on the whole, not very inclusive.

At the level of representation, these theories all represent the same kind of entity, namely, the substance that we know as chlorine. The retail argument in this case is basically the same as the Scheele-inspired retail argument from section 6. Scheele's real contribution was the discovery of a method for producing the substance that came to be known as chlorine. Chemists working in the aftermath of Scheele's discovery used his method, and developed other methods as well. Since Scheele, Lavoisier, Berzelius, and Davy shared various methods and produced the same substance, they also theorized about the same substance. More specifically, Scheele's theory presents dephlogisticated acid of salt, Davy's theory presents chlorine, Lavoisier's and Berzelius's theories present oxymuriatic acid, and all of these theories represent chlorine. Hence, although we haven't individuated the kinds of entities very inclusively at the level of presentation, at the level of representation, we can adopt a more encompassing form of realism about the substance that was variously known as dephlogisticated acid of salt, oxymuriatic acid, and chlorine.

However, my argument faces a potential objection. For some time, philosophers of science have puzzled over the question of whether a theory that is not strictly true of some kind of theoretical entity can nevertheless represent it. Since Scheele's, Lavoisier's, and Berzelius's theories are not even approximately true when it comes to chlorine, perhaps those theories cannot represent chlorine. In order to respond to this objection, it's necessary to first emphasize that Scheele, Lavoisier, and Berzelius were all able to produce relatively pure samples of chlorine, which they used in their experiments. I take it that they couldn't fail to theorize about a substance that they could exercise such control over in their experiments. And since they theorized about chlorine, their theories represent chlorine.

This response to the objection shows that what really does the work in the retail argument for chlorine is Scheele's experiments, not his theory. This kind of view is, of course, not new. Hacking (1983) famously argued that our best guide to the reality of a theoretical entity consists in what scientists can do with it. More recently, Chen (2016, 365) has suggested that, "if a scientist can realize the individuality of an object in a particular experiment, then she has provided the strongest evidence . . . to warrant the reality of the object." And Chang (2011) has argued that chemists' operations for producing various substances (e.g., oxygen gas) justify them in retaining certain theoretical entities (e.g., oxygen), even when the theories in question have been rejected. If retail realists were to go so far as to defend some kind of experimental criterion for the reality of theoretical entities in general, they would have to show how, in doing so, they could avoid relying on the wholesale arguments that they want to reject. Instead of doing that, I'll simply note that experiments are doing the work in this retail argument, while remaining noncommittal about what does the work in other retail arguments.

Two consequences of my arguments in this chapter are (1) the more selective form of realism that we take towards kinds of entities at the level of representation requires that we individuate those kinds of entities less inclusively at the level of presentation, and (2) the more encompassing form of realism that we take towards kinds of entities at the level of representation is possible regardless of how inclusively we individuate kinds of entities at the level of presentation. This second consequence does not entail that the issue of individuation is unimportant when it comes to cases that warrant the more encompassing form of realism. On the contrary, being clear about individuation in such cases allows for a more nuanced realism. In the case of oxymuriatic acid, focusing on the issue of individuation allows us to simultaneously respect the fact that there were important theoretical differences among these four chemists, and the fact that they were nonetheless working with the same chemical substance. It's not clear how one can develop such a nuanced realism while ignoring the issue of individuation. By shifting from realism about our best theories to realism about particular kinds of theoretical entities, retail realism allows for a more nuanced realism than wholesale realism does. What I'm suggesting is that, by focusing on the issue of individuation, retail realists can have an even more nuanced view.

8 Conclusion

By this point, I hope to have shown that it's important for retail realists to address questions regarding the individuation of kinds of theoretical entities. When they claim to be realists about a particular kind of entity, they ought to be clear about how they individuate that kind of entity, and about why they opt for that way of individuating it. By employing the notion of the inclusiveness of individuation, it's possible for them to adopt a more selective form of realism in some cases, and a more encompassing form of realism in others.

Acknowledgements

Thanks to Hasok Chang, Ruey-Lin Chen, In-Rae Cho, Melinda Fagan, Derek Leben, Min Ouyang, Nicholas Tebben, Karen Yan, and two reviewers for comments on earlier drafts and presentations of the material in this chapter. Thanks to audiences at Kyoto University, National Chung Cheng University, and National Taiwan University for helpful questions and comments. Finally, much of the research for this chapter was completed during my time as a postdoctoral fellow at the Institute of European and American Studies at Academia Sinica, and so I thank the institute, and especially my sponsor, Jih-Ching Ho.

Notes

1. Magnus and Callender argue in favor of dissolution on the grounds that the two most influential arguments in the debate, namely, NMA and PMI, embody the base rate fallacy. Since

I'm concerned with their positive proposal, namely, retail realism, in what follows, I'll focus on that, as opposed to their reasons for dissolving the realism debate.

2. See, e.g., Psillos 1999, ch. 6.

3. See, e.g., Ladyman and Ross 2007, 132-140.

4. See Ashbee 2007, 18; Chang 2010, 51; and Lowry 1915, 210 for the claim that Scheele's "manganese" was pyrolusite. I'll follow Scheele's usage, and use the term 'manganese' to refer to pyrolusite.

5. That said, Scheele does entertain the possibility that Stahl may have obtained it previously ([1774] 1931, 32).

6. Gay-Lussac and Thénard (1809, 358) had entertained this view about a year earlier. But Berthollet convinced them to reject it (Crosland 1980, 102; Gray, Coates, and Åkesson 2007, 45).

7. Kirwan (1798, 4-5) was a major proponent of this view, and he lists eleven chemists who, at one point or another, identified phlogiston with hydrogen. Cavendish (1766, 145) is another example, though he later gave up this view. Scheele is notably absent from Kirwan's list.

8. See Siegfried 1964.

9. Though see Gray et al. (2007, 46-52) for the view that, by the time Davy presented his arguments, most chemists no longer strictly adhered to the oxygen theory of acidity.

10. For a good summary of Berzelius's arguments against Davy's views, see Gray et al. 2007, 61-64).

11. See Chang 2011, 417 for a similar conclusion regarding the existence of Lavoisier's radical. I'll say more about anti-realism regarding Lavoisier's radical in section 6.

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