Retail Realism and Wholesale Treatments of Theoretical Entities

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Short Abstract: According to retail realism, we ought to abandon wholesale arguments, which purport to demonstrate realism or anti-realism about theoretical entities in general, and embrace retail arguments, which purport to demonstrate realism or anti-realism about specific kinds of theoretical entities. My aim is to argue that there is a further wholesale element that retail realism must avoid in order to qualify as a viable position. In order to do so, I distinguish between what I call wholesale and retail treatments of theoretical entities. Wholesale treatments individuate theoretical entities in such a way that the same entity can appear in distinct theories. In that case, realism about a given entity implies realism about that entity as it appears in a number of distinct theories. Retail treatments, on the other hand, individuate theoretical entities more finely, so that distinct theories actually involve distinct entities. In that case, realism about one entity needn't imply realism about a similar, but distinct, entity. I argue that retail realists ought to reject wholesale treatments in favor of retail treatments, and I do so by examining a case from the history of chemistry involving the hypothetical constituent of hydrochloric acid known as the muriatic radical. I argue that there are distinct muriatic radicals in distinct theories, and that we ought to be realists about some, but not others. Hence, in this case, a retail treatment is preferable to a wholesale one, and I conclude by discussing why the combination of retail realism and retail treatments constitutes an attractive position within the scientific realism debate more generally.

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Long Abstract: One of the central questions of the scientific realism debate concerns the existence of theoretical entities. According to retail realism, we ought to abandon wholesale arguments, which purport to demonstrate realism or anti-realism about theoretical entities in general, and embrace retail arguments, which purport to demonstrate realism or anti-realism about specific kinds of theoretical entities. My aim is to argue that there is a further wholesale element that retail realism must avoid in order to qualify as a viable position. In order to do so, I distinguish between what I call wholesale and retail treatments of theoretical entities. Wholesale treatments individuate theoretical entities in such a way that the same entity can appear in distinct theories, which may contain conflicting descriptions of the entity in question. In that case, realism about a given entity implies realism about that entity as it appears in a number of distinct theories. Retail treatments, on the other hand, individuate theoretical entities more finely, so that distinct theories actually involve distinct entities. In that case, realism about one entity needn't imply realism about a similar, but distinct, entity. I argue that retail realists ought to reject wholesale treatments in favor of retail treatments.

In order to make this argument, I discuss a case from the history of chemistry, namely, the case of the muriatic radical. In the late eighteenth century, Antoine Lavoisier held that all acids are composed of oxygen and another component, which Lavoisier called the radical; and that acids differ from one another insofar as they have different radicals. Though he couldn't decompose muriatic acid to show that it contains oxygen, he hypothesized that it is composed of oxygen and an unknown radical—the muriatic radical. In 1810, Humphry Davy argued, contrary to Lavoisier's hypothesis, that muriatic acid is composed of hydrogen and chlorine, and so it is what we now call hydrochloric acid. After an initial period of opposition to Davy's views, Jöns Jacob Berzelius went on to develop a view of acids that can be seen as a synthesis of Lavoisier's and Davy's views. Lavoisier was correct about so-called oxygenous acids, while Davy was correct about muriatic acid because the latter is not an oxygenous acid, but rather a hydracid. Hydracids are composed of hydrogen combined with a radical, in which case the muriatic radical for Berzelius is chlorine.

A wholesale treatment would imply that both Lavoisier and Berzelius were employing the same theoretical entity. A retail treatment, on the other hand, would imply that Lavoisier's radical and Berzelius's radical are distinct theoretical entities. I argue in favor of a retail treatment, on the grounds that

distinguishing Lavoisier's radical from Berzelius's allows us to be anti-realists about the former, and realists about the latter. In this case, then, a retail treatment yields a desirable kind of selective realism which is unavailable to a proponent of a wholesale treatment. I conclude by discussing why the combination of retail realism and retail treatments constitutes an attractive position within the scientific realism debate more generally.

Contents

1 Retail Realism

One of the central questions of the scientific realism debate is whether or not the entities posited in our best scientific theories exist. Realists claim that such theoretical entities do exist, while anti-realists either claim that they don't, or that we ought to be agnostic about whether they do.

Magnus and Callender (2004) have pointed out that there are, in fact, two types of arguments that philosophers involved in the realism debate, whether realists or anti-realists, use in order to answer questions about the existence of theoretical entities. On the one hand, there are "wholesale arguments," which are "arguments about all or most of the entities posited in our best scientific theories"; on the other hand, there are "retail arguments" which are "arguments about specific kinds of things such as neutrinos, for instance" (ibid.: 321). Magnus and Callender go on to argue that the only viable way forward in the realism debate requires that we abandon wholesale arguments, and focus on retail arguments. Once we do, we must reject wholesale realism and anti-realism. The only kind of realism that survives is a kind of retail realism about some entities but not others—as they put it, "there may be good reasons to be a realist about neutrinos, an anti-realist about top quarks, and so on" (ibid.: 333). They admit that such a situation may cause discomfort to both realists and anti-realists, but this is a price that Magnus and Callender are willing to pay to make progress in the debate.

A glance at recent work in the realism debate shows that there is much of which Magnus and Callender would approve. As Dicken (2013) argues, one can find retail realism in the work of a number of philosophers, including Psillos (2009), Saatsi (2010), and Stanford (2006). Moreover, given that much of the debate has centered on specific kinds of entities, like phlogiston, caloric, and the optical ether, there is no shortage of retail arguments on offer.[1] While wholesale arguments have not been abandoned by all philosophers involved in the debate, it's fair to say that many philosophers have chosen to focus their efforts on retail arguments instead.

There are at least two main reasons why philosophers have deemed it a good idea to abandon wholesale arguments in favor of retail arguments. The first has to do with what are perhaps the two most influential arguments in the realism debate, namely, the no-miracles argument and the pessimistic

[1] See, for example, the discussion of phlogiston in Ladyman (2011), the discussion of caloric in Chang (2003), and the discussion of the optical ether in Cordero (2011).

meta-induction. According to the no-miracles argument, the explanatory and predictive success of our best scientific theories would be miraculous if those theories weren't genuinely referential and at least approximately true. This argument is usually taken to support some form of realism. The pessimistic meta-induction, on the other hand, draws upon our past theories, which were successful but false, as an inductive basis for inferring inductively that our current successful theories are false as well. It is usually taken to support some form of anti-realism. A number of philosophers have argued that both arguments are best construed as statistical arguments, and that as such, both suffer from the base rate fallacy. Howson (2000, 52–54) has argued that the no-miracles argument ignores the base rate of true theories in a population, and Lewis (2001) has argued that the pessimistic meta-induction does as well. The unavailability of these base rates is Magnus and Callender's primary reason for thinking that realists and anti-realists are mostly talking past one another, and for abandoning wholesale arguments in favor of retail arguments.

The second reason for abandoning wholesale arguments has to do with Laudan's confutation of realism (Laudan, 1981).[2] In the spirit of the no-miracles argument, realists claim that the success of our best theories provides evidence for their approximate truth. Laudan, in response, presents a long list of purported counterexamples to this claim. The list includes the phlogiston theory of combustion, the wave theory of light, and the caloric theory of heat, which were all quite successful in their day. But given that these theories involve terms ('phlogiston,' 'ether,' and 'caloric') that the realist categorizes as paradigm cases of empty names, these are theories that, by the realist's own lights, presumably fail to be even approximately true.[3] Given that Laudan's argument depends on the details of the theories he discusses, responses to his argument, and responses to those responses, have focused on specific entities posited in specific theories. As such, these responses count as retail arguments, as opposed to wholesale arguments. Laudan's argument has also motivated philosophers to search for other theories that may spell trouble for the realist, which, in turn, has led to even more retail arguments.[4]

[2]Although it is common to read Laudan as advancing a form of the pessimistic meta-induction, Lyons (2002) shows that he is not.

[3]But as Frost-Arnold (2011, 2013) has recently argued, this may not render such theories false—given some commonly-held views in semantics, such theories may actually lack truth-values.

[4]Vickers (2013) provides a useful list of the theories that such philosophers have dis-

For these and other reasons, I take it that retail realism represents a genuine step forward in the realism debate. That said, there are a number of ways in which to develop this position, and I'll argue that some ways are better than others.

To that end, in section 2, I'll distinguish two ways of developing retail realism, which I call wholesale and retail treatments of theoretical entities. Wholesale treatments individuate theoretical entities in such a way that the same entity can appear in distinct theories, which may contain conflicting descriptions of the entity in question. In that case, realism about a given entity implies realism about that entity as it appears in a number of distinct theories. Retail treatments, on the other hand, individuate theoretical entities more finely, so that distinct theories actually involve distinct entities. In that case, realism about one entity needn't imply realism about a similar, but distinct, entity. My primary goal is to argue that retail realists ought to reject wholesale treatments in favor of retail treatments.

My argument will make use of a case from the history of chemistry, namely, the case of the muriatic radical, and in section 3, I discuss the details of that case. In the late eighteenth century, Antoine Lavoisier held that all acids are composed of oxygen and another component, which Lavoisier called the radical; and that acids differ from one another insofar as they have different radicals. Though he couldn't decompose muriatic acid to show that it contains oxygen, he hypothesized that it is composed of oxygen and an unknown radical—the muriatic radical. In 1810, Humphry Davy argued, contrary to Lavoisier's hypothesis, that muriatic acid is composed of hydrogen and chlorine, and so it is what we now call hydrochloric acid. After an initial period of opposition to Davy's views, Jöns Jacob Berzelius went on to develop a view of acids that can be seen as a synthesis of Lavoisier's and Davy's views. Lavoisier was correct about so-called oxygenous acids, while Davy was correct about muriatic acid because the latter is not an oxygenous acid, but rather a hydracid. Hydracids are composed of hydrogen combined with a radical, in which case the muriatic radical for Berzelius is chlorine.

A wholesale treatment would imply that both Lavoisier and Berzelius were, in one way or another, employing the same theoretical entity, while a retail treatment would imply that Lavoisier's radical and Berzelius's radical are distinct theoretical entities. In section 4, I argue in favor of a retail treatment, on the grounds that distinguishing Lavoisier's radical from Berzelius's

cussed, as well as some previously undiscussed cases that are of potential interest.

allows us to be anti-realists about the former, and realists about the latter. In this case, then, a retail treatment yields a desirable kind of selective realism which is unavailable to a proponent of a wholesale treatment. Finally, in section 5, I conclude by discussing why the combination of retail realism and retail treatments constitutes an attractive position within the scientific realism debate more generally.

2 Wholesale and Retail Treatments of Theoretical Entities

My primary goal is to argue that there is a further wholesale element that retail realism must avoid so as to qualify as a viable position. In order to do so, my aim in this section is to introduce the notions of wholesale and retail treatments of theoretical entities. In the remainder of the paper, I will argue that retail realists should avoid the former, and adopt the latter instead.

Before we're able to see what these treatments are and how they differ from one another, though, we must start by first recalling that retail realists restrict their arguments to specific kinds of theoretical entities. To take a concrete example, in response to the question "Are there atoms?", Magnus and Callender claim that a retail realist will cite "the same evidence scientists use to support the atomic hypothesis; e.g., Einstein and Smoluchowski's Brownian motion theory and the experiments by Perrin in 1908" (op. cit.: 321). More generally, retail realists seek to answer questions of the form: 'Are there xs?', where x stands for some theoretical entity. Realists about x will answer 'Yes,' while anti-realists about x will answer 'No.'

In order to avoid familiar puzzles concerning speaking of what is not, I suggest that these questions, along with the notion of a theoretical entity, be understood in a particular way. To a first approximation, realists and anti-realists share an understanding of a given theoretical entity in a sense similar to the one in which theists, atheists, and agnostics share an understanding of God—there is some consensus regarding what the entity would be like if it existed, and the debate concerns whether it does, in fact, exist. This notion of a theoretical entity can usefully be understood in terms of what Rheinberger (1997) calls "epistemic things" and what Chang (2011) calls "epistemic objects." In Chang's words, these are "objects as we conceive them in our interaction with them, without a presumption that our

conceptions correspond in some intractable sense to the shape of an 'external' world that is entirely divorced from ourselves" (ibid.: 413). As I will use the terminology, then, a theoretical entity is an epistemic object in Chang's sense—it's a conception involved in our theorizing about the world. When philosophers engaged in the realism debate ask whether a theoretical entity exists, then, they are not asking whether scientists currently have or previously had such-and-such a conception. Instead, they are asking whether there is the right kind of correspondence between that conception and entities that exist independently of our minds, which I will call empirical entities.[5] Realists claim that there is such a correspondence, while antirealists either deny that there is, or claim that we cannot know.

In that case, if retail arguments are to provide any guidance regarding the attitudes which we ought to take towards various theoretical entities, one first needs to know how to individuate theoretical entities. A glance at the history of science shows that this is not as straightforward as one might initially think. Consider, for example, Dalton's atom in contrast to Boscovich's, or Stahl's phlogiston in contrast to Priestley's, or Lavoisier's caloric in contrast to Carnot's, or Dirac's positron in contrast to Anderson's, or Lorentz's electron in contrast to Millikan's. In such cases, one can ask whether the scientists in question were working with the same theoretical entity, or with distinct entities.

At this point, we can be clear about what wholesale and retail treatments of theoretical entities amount to. Wholesale treatments are committed to the claim that the same theoretical entity can appear in distinct theories, even if those theories involve conflicting descriptions of the entity in question. Retail treatments, on the other hand, are committed to the claim that distinct theories involve distinct theoretical entities, even if those entities sometimes share striking similarities. Retail treatments, then, commit one to individuating entities as finely as one individuates theories. Wholesale treatments, in contrast, commit one to individuating entities at a grain coarser than the grain at which one individuates theories. Retail and wholesale treatments, then, concern different ways of individuating theoretical entities.

These competing ways of individuating theoretical entities have implications for the realism debate, which I've characterized as involving questions

[5]Being more precise about the right kind of correspondence would obviously involve addressing many central issues in philosophy, and for the sake of brevity, I must leave these issues unaddressed and work with an intuitive notion of the correspondence in question.

about the relations between our theoretical entities and empirical entities that exist in the world. Retail realists are thus faced with a choice concerning which treatment to adopt, and each treatment lends itself to a distinct position regarding realism about a given theoretical entity. On the one hand, if a retail realist adopts a wholesale treatment, then realism about some theoretical entity implies realism about that entity as it appears in a number of distinct theories. On the other hand, if a retail realist adopts a retail treatment, then realism about some theoretical entity needn't imply realism about a similar, but distinct, entity drawn from a distinct theory. And, of course, similar remarks apply to anti-realism about various kinds of entities. In short, then, wholesale treatments lead to either wholesale acceptance or wholesale rejection of a theoretical entity as it appears in a number of distinct theories, while retail treatments allow for the possibility of proceeding on a case-by-case basis, which can lead to a kind of selective realism about some theoretical entities, but not others.

While the terminology that I have chosen to adopt here may be new, the ideas themselves are not, and both wholesale and retail treatments have had their defenders. To take a prominent example of a defender of the latter, (Kuhn, 2012/1962, 102) commits himself to a retail treatment of mass when he argues that Newton's mass and Einstein's mass have distinct physical referents. Kuhnian incommensurability thus implies that wholesale treatments ought to be rejected in favor of retail ones. More generally, any holistic view of the meaning of theoretical terms shares this commitment. If the meaning of a theoretical term is fixed entirely by a set of descriptions or operations, then any change in the set of those descriptions or operations results in a distinct entity. To take a recent example, (Worrall, 2011, 169) argues that our knowledge of theoretical entities is purely descriptive, and that the Ramsey sentence of a theory yields the relevant description. Distinct theories with distinct Ramsey sentences will therefore involve distinct theoretical entities, in which case Worrall's position entails a commitment to retail treatments of theoretical entities.

Wholesale treatments have had prominent defenders as well. For some time now, scientific realists in the tradition of Boyd (1981) and Putnam (1975) have been opposed to Kuhnian incommensurability and to holistic views of meaning more generally, and have thus embraced wholesale treatments over retail ones. Putnam's work on meaning and reference is particularly important in this regard, as it showed the possibility of distinct theories referring to the same entity. As is well known, Putnam's work, combined with

that of Kripke (1980), convinced many philosophers that the mechanisms in virtue of which reference is fixed, and those in virtue of which distinct speakers can refer to the same entity, must, at least in part, be causal. This conviction has survived for some time now, as one can see in more recent work by Psillos (1999), and Stanford and Kitcher (2000), who incorporate causal elements into their theories of reference so as to allow for wholesale treatments of theoretical entities.

These views, at least as I have discussed them, individuate theoretical entities by appeal to specific views about meaning, and it may seem that such consequences can only result from conflating issues in the philosophy of language with issues in metaphysics. But this is not the case. Given that the notion of theoretical entity at issue here concerns our conceptions, the question of individuation concerns the individuation of those conceptions. The question of realism concerns the correspondence between those conceptions, individuated in a particular way, and empirical entities that exist independently of us.

While wholesale and retail treatments are not new, they have, in the past, been wedded to wholesale positions in the realism debate, with wholesale realists generally advocating wholesale treatments and wholesale anti-realists advocating retail treatments.[6] Although this may be well-traveled ground when it comes to wholesale positions in the debate, it's as yet an open question whether retail realists ought to opt for wholesale treatments or retail ones. Given the terminology that I've introduced, my view that they should opt for the latter should come as no surprise.

In the remainder of the paper, I will argue that the commitment to wholesale treatments is a wholesale element that retail realists ought to reject, and I will do so by examining a case from the history of chemistry involving the so-called muriatic radical. My goal is to argue that there are distinct muriatic radicals in distinct theories, and that we ought to be realists about some, but not others. In that case, a retail treatment is preferable to a wholesale one. Given the importance of the historical details to the argument that I aim to give, in the next section, I concern myself with an examination of those details.

[6]There are, of course, exceptions—for example, Worrall (op. cit.) defends a form of structural realism, while Stanford (2006) has gone on to defend a form of anti-realism.

3 The Case of the Muriatic Radical(s)

My goal in this section is to discuss the case of the muriatic radical, which chemists in the late eighteenth and early nineteenth centuries hypothesized to be a constituent of muriatic acid, now known as hydrochloric acid. Though I'll sometimes write of 'the' muriatic radical for ease of exposition, I will argue in the next section that this locution is a bit misleading—since we can and should distinguish different radicals in different theories, it would be more accurate to call it the case of the muriatic *radicals*. For the time being, though, I will attempt to remain neutral on this issue, and I will focus on the radical as it appears in the work of three chemists, namely, Lavoisier, Davy, and Berzelius. However, before doing so, it will be necessary to say something about the state of chemistry before chemists hypothesized the muriatic radical.

3.1 The Prehistory of the Muriatic Radical

Chemists in the later years of the eighteenth century worked with a scheme for classifying substances that included a kind of substance that they called acids, and they used a number of properties in order to distinguish acids from non-acids. Nicholson's *Dictionary of Chemistry* enumerates these properties as follows:

> 1. Their taste is sour and corrosive, unless diluted with water. 2. They change blue vegetable colors to a red. 3. Most of them unite with water in all proportions; and many have so strong an attraction to that fluid as not to be exhibited in the solid state. 4. At a moderate temperature, or in the humid way, they combine with alkalis so strongly as to take them from all other substances. 5. They combine with most bodies, and form combinations attended with many interesting phenomena; upon the due explanation of which a great part of the science of chemistry depends. (Nicholson, 1795, 2)

The kind *acids*, then, was delineated, not in terms of the inner constitution of such substances, but phenomenologically, in terms of various properties that chemists at the time could observe.

Of all the substances that chemists classified as acids at the time, two will be important in what follows. The first was variously referred to as

acid of sea-salt, marine acid, and muriatic acid, and it is what we now call hydrochloric acid. The second was variously referred to as dephlogisticated marine acid, oxygenated muriatic acid, and oxymuriatic acid, and it is what we now call chlorine. For the sake of clarity, in what follows I'll settle on a single name for each, and I'll refer to these two substances as muriatic acid and oxymuriatic acid, respectively.

Chemists had been working with muriatic acid for some time, but oxymuriatic acid was not isolated until 1774. Scheele was the first to do so, and though he classified the substance as an acid, he notes that it has the properties that chemists associated with acidity to a lesser extent than other acids (Scheele, 1786/1774, 92–93). Subsequent chemists both followed Scheele's classification of the substance as an acid, and his acknowledgement that, even so, it wasn't much of an acid.[7]

As a proponent of the phlogiston theory, Scheele put forward the view that oxymuriatic acid is muriatic acid devoid of its phlogiston—hence the terminology "dephlogisticated marine acid" (ibid.: 93). On Scheele's view, then, oxymuriatic acid is the simpler substance, and it is a component of muriatic acid. But while chemists followed Scheele's classification of this new substance, not all followed his views regarding the constitution of the two acids.

3.2 Lavoisier's Oxygen Theory of Acidity

In the later years of the eighteenth century, Lavoisier developed his oxygen theory of acidity. His central claim regarding acids is "that oxygen is an element common to them all, which constitutes their acidity" (Lavoisier, 1965/1789, 65). He supports this claim by appealing to three examples of substances that combine with oxygen to form acids: phosphorus, sulphur, and carbon, according to Lavoisier, each combine with oxygen to form phosphoric acid, sulphuric acid, and carbonic acid, respectively (ibid.: 60–65). He concludes 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" (ibid.: 65). While all acids for Lavoisier contain oxygen, they contain different bases, or synonymously, radicals—these constituent substances are what ground the differences between differ-

[7]For the latter point, see, for example, Berthollet (1788, 279), Lavoisier (1965/1789, 73), Nicholson (1795, 27), and Davy (1810a, 70).

ent kinds of acids, and they can be simple or compound (ibid.: 115). In the examples mentioned above, phosphorus, sulphur, and carbon are the bases phosphoric acid, sulphuric acid, and carbonic acid, respectively.[8]

While Lavoisier was able to show that a number of acids contain oxygen, 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 (ibid.: 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*, deriving this name, after the example of Mr Bergman and Mr de Morveau, from the Latin word *muria*, which was anciently used to signify sea-salt. (ibid.: 71–72)

Lavoisier's reference to Guyton de Morveau is noteworthy, as the latter hypothesizes the radical in a similar passage:

> Analogy induces us to think that the muriatic acid has an acidifiable base, as well as the carbonic, sulphuric, and phosphoric acids, which like the bases of these latter, serves to give a distinct and particular property to the produce of a combination of oxygen. We could not express this substance otherwise than by the name muriatic *radical* or muriatic radical principle . . . (Guyton de Morveau, Lavoisier, Berthollet, and Fourcroy, 1788, 33–34)

In accordance with the oxygen theory of acidity, acids are not simple substances, and muriatic acid was no exception. Proponents of that theory

[8]This use of terminology was not restricted to acids, but was applied to kinds of substances in general. For example, gases are a kind of substance, and for Lavoisier, all gases contain caloric; different kinds of gases differ from one another in virtue of the fact that they have different bases (oxygen, hydrogen, etc.) (ibid.: 15).

therefore had to hypothesize that it contains oxygen, like all other acids, and a hypothetical base or radical—the muriatic radical.

Lavoisier and his followers also theorized about the nature of oxymuriatic acid, which they viewed to be a compound of oxygen and muriatic acid (Lavoisier, 1965/1789, 73; Berthollet, 1788, 279). The view of the oxygen theorists is thus a complete reversal of Scheele's view, according to which oxymuriatic acid is the simpler substance. This makes sense once one recognizes that the substance that phlogiston theorists like Scheele labeled dephlogisticated air is the oxygen of the oxygen theorists. The considerations that led Scheele to classify oxymuriatic acid as muriatic acid devoid of its phlogiston thus led the oxygen theorists to classify it as muriatic acid saturated with oxygen. Thus, the muriatic radical is a constituent, not only of muriatic acid, but of of oxymuriatic acid as well.

In sum, Lavoisier's oxygen theory of acidity yields the following view of the two substances: muriatic acid is made up of the muriatic radical and oxygen, while oxymuriatic acid results from adding oxygen to muriatic acid. For Lavoisier and those who shared his views on acidity, the muriatic radical was therefore a hypothetical component of both of these substances.

3.3 Davy's Work on the Acids

One of the outstanding issues in chemistry at the time was to decompose these acids and isolate the muriatic radical. One chemist who attempted to do so was Davy, who, for some time, shared Lavoisier's view that both acids contain oxygen. But in 1810, the year in which his work on the acids culminated, Davy rejects Lavoisier's view. In a paper read in July of that year, Davy claims that the presence of oxygen in the acids has not been demonstrated:

> in the usual cases where oxygene 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, it is scarcely possible to avoid the conclusion, that the oxygene 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 in oxymuriatic acid gas. (Davy, 1810b, 236)

What really happens, then, is that the oxymuriatic acid decomposes the water, combining with the hydrogen to form muriatic acid and 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 oxygen in muriatic acid is similarly hypothetical.

Davy's view of muriatic acid, then, is that it is made up of oxymuriatic acid and hydrogen, and in a striking passage, he concludes that Scheele's phlogiston theory yields the correct view of the acids, while Lavoisier's oxygen theory does not:

> It is evident from this series of observations, that SCHEELE'S view, (though obscured by terms derived from a vague and unfounded general theory,) of the nature of the oxymuriatic and muriatic acids, may be considered as an expression of facts; whilst the view adopted by the French school of chemistry, and which, till it is minutely examined, appears so beautiful and satisfactory, rests in the present state of our knowledge, upon hypothetical grounds. (ibid.: 237)

Given that Scheele held that muriatic acid contains oxymuriatic acid and phlogiston, it may not be obvious how his view can be "an expression of facts." This becomes clear once one recognizes that many chemists at the time identified phlogiston with hydrogen. Priestley did so as early as 1782 in his correspondences (Priestley, 1892, 33), and Kirwan did as well (Kirwan, 1789, 4–5). By the early nineteenth century, the identification of phlogiston and hydrogen was more-or-less commonplace in the work of many chemists. To take an example from Davy's work, when discussing some hypotheses regarding the constitution of metals, he writes of "the adherence of their phlogiston or hydrogene," without pausing to explain the identification of phlogiston and hydrogen (Davy, 1808, 364). Given this identification, Scheele's view amounts to the claim that muriatic acid contains oxymuriatic acid and hydrogen, which is essentially correct.

While Davy provides some moderate praise for Scheele's view, he also points to the shortcomings of the oxygen theory. If the principle of acidity, namely, oxygen, isn't present in these two acids, then that theory would seem to be in serious trouble. Davy even goes so far as to speculate that

oxymuriatic acid may be another principle of acidity, and that "on this idea muriatic acid may be considered as having hydrogene for its basis, and oxymuriatic acid for its acidifying principle" (Davy, 1810b, 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(ibid.: 241–242). It's probable that this analogy is what led him to speculate that oxymuriatic acid is the acidifying principle, leaving hydrogen as the muriatic radical.

In the Bakerian Lecture that he gave in November of 1810, Davy argues for a claim that Gay-Lussac and Thénard considered and rejected about a year earlier, namely, that oxymuriatic acid ought to be considered an element (Gay-Lussac and Thénard, 1809, 358). And in light of the fact that oxymuriatic acid "has not as yet been decompounded," and is "elementary as far as our knowledge extends" (Davy (1811), 1), Davy pushes for a change in terminology:

> To call a body which is not known to contain oxygene, and which cannot contain muriatic acid, oxymuriatic acid, is contrary to the principles of that nomenclature in which it is adopted ... (ibid.: 32)

He goes on to suggest the names 'chlorine,' and 'chloric gas.' 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' (ibid.: 33), his work shows why we now refer to that acid as hydrochloric acid.

3.4 Berzelius's Work on Hydracids

While Davy is credited with these achievements today, his views did not go unchallenged. One of his most prominent critics was Berzelius, who, for some time, opposed Davy's views and defended a form of Lavoisier's oxygen theory of acidity. Berzelius frames his view in terms of Dalton's atomic theory, and claims that muriatic acid contains one atom of muriatic radical and two atoms of oxygen, while oxymuriatic acid contains one atom of muriatic radical and three atoms of oxygen (Berzelius, 1813, 254).[9] He

[9]Though elsewhere, he puts this in terms of volumes as opposed to atoms (Berzelius, 1816, 276).

emphasizes that, although pure muriatic acid does not contain water as a component, that acid is incapable of existing without water, and thus the acid with which we are familiar is impure (Berzelius, 1813, 254; Berzelius, 1816, 273). In theory then, one can add oxygen to pure muriatic acid to obtain oxymuriatic acid. But given that muriatic acid is always mixed with water, there's a sense in which one can obtain the impure acid by adding hydrogen to oxymuriatic acid. In such a reaction, the oxymuriatic acid loses a volume of oxygen, and so is converted to pure muriatic acid. That volume of oxygen combines with the hydrogen to form water, and hence the result is impure muriatic acid. Regarding the radical in particular, Berzelius claims that its nature is still unknown, and that chemists have not succeeded in isolating it (Berzelius, 1813, 254; Berzelius, 1816, 263).

Berzelius eventually dropped his opposition to Davy, and accepted the latter's view that muriatic acid is made up of hydrogen and chlorine, which he, following Davy, regarded as an element (Berzelius, 1825, 180–181). However, his theorizing about the nature of muriatic acid, and of acids more generally, continued. More specifically, he claims that there is a class of acids, namely, hydracids, of which muriatic acid is an example (ibid.: 181). 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" (ibid.: 180). Berzelius goes on to claim 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" (ibid.: 180). It follows, then, that on Berzelius's view, chlorine is the muriatic radical.

Berzelius's view can be seen as a synthesis of the views of both Davy and Lavoisier. On Berzelius's view, Davy, and not Lavoisier, was correct about the constitution of muriatic acid; however, while Lavoisier's theory is incorrect when it comes to muriatic acid and other hydracids, it gives the correct results if restricted to oxygenous acids.

Berzelius' work on hydracids shows that the muriatic radical still had a place in chemistry well after Davy's determination of the constituents of muriatic acid. But, of course, this was not the case for long, and our current theories of acidity make no reference to the acidifable radicals and bases of the late eighteenth and early nineteenth centuries.

4 How Many Muriatic Radicals Are There?

My goal at this point is to argue that, when it comes to the case of the muriatic radical(s), a retail treatment is preferable to a wholesale one. More specifically, I'll argue that we ought to view Lavoisier's radical and Berzelius's radical as two distinct theoretical entities, as opposed to one and the same entity with which two scientists worked. The main thrust of my argument is that, if we distinguish Lavoisier's radical from Berzelius's radical, there are good reasons to be anti-realists about the former, and realists about the latter. More specifically, I'll argue that we ought to be anti-realists about Lavoisier's radical, because the right kind of correspondence between this theoretical entity and an empirical entity is lacking; and that we ought to be realists about Berzelius's radical, because there is such a correspondence with an empirical entity, namely, chlorine. If we adopt a wholesale treatment, this kind of selective realism is unavailable, since such treatments do not individuate theoretical entities at a grain fine enough. Retail treatments, however, do individuate theoretical entities at a grain fine enough, and so allow for this kind of selective realism. I conclude, then, that the case of the muriatic radical requires a retail treatment as opposed to a wholesale one.

4.1 Anti-realism About Lavoisier's Radical

In light of the fact that Lavoisier's theory of acidity was completely wrong, and the fact that he was completely wrong about the nature of muriatic acid and of oxymuriatic acid, we ought to be anti-realists about Lavoisier's radical. He held that both substances contain oxygen, which, of course, turned out to be false; and he held that both substances share another component, which turned out to be false as well. Moreover, he held that this other component, the muriatic radical, had not been isolated, and so he made no attempt to identify the radical with any well-known substance which chemists could isolate. For Lavoisier, then, the muriatic radical was that substance which combines with oxygen to form both muriatic acid and oxymuriatic acid. If that is what the muriatic radical is, then the most reasonable conclusion to draw is that there is no such thing. In that case, we ought to be anti-realists about Lavoisier's radical—there is no empirical entity that corresponds to this theoretical entity.

Although the muriatic radical is not often discussed by philosophers of science, Chang is an exception, and his work provides some support for an

anti-realist attitude towards Lavoisier's radical. Though he doesn't distinguish different radicals in different theories, when he claims that the radical does not exist, he has in mind Lavoisier's radical (Chang 2011, 417; 2012b, 54). A realist about Lavoisier's radical would presumably have to answer the question: which constituent of muriatic acid and of oxymuriatic acid is the radical, and which is the principle of acidity? But as Chang rightly points out, from the standpoint of modern chemistry, it makes no sense to ask such a question (2011, 417). And asking such a question from the standpoint of Lavoisierian chemistry leads to anti-realism about Lavoisier's radical. For Lavoisier, oxygen is the sole principle of acidity, and so there is nothing to point to in order to support the claim that hydrogen is the radical, over the claim that chlorine is, and vice versa. Moreover, since Lavoisier held that muriatic acid is a component of chlorine, the latter substance would be a particularly poor candidate for the radical, since this would entail that the two substances are components of each other. But while hydrogen might then seem to be a better candidate, this is not the case, given that it is not a component of chlorine. Anti-realism about Lavoisier's radical, then, would seem to be the most reasonable option.

It may be objected that I'm being uncharitable to Lavoisier here, given that there are two perfectly good entities with which one can identify his radical, namely, hydrogen and chlorine. Moreover, one needn't actually choose between them. For example, one might employ Field's (1973) notion of partial denotation, and defend the view that 'muriatic radical' denotes both hydrogen and chlorine. Or one might employ McLeish's (2006) notion of disjunctive partial reference, and claim that 'muriatic radical' denotes either hydrogen or chlorine. In that case, perhaps one can be a realist about Lavoisier's radical after all.

These strategies may yield a kind of realism about Lavoisier's radical, but it's not the kind of realism with which I am concerned here. The kind of realism that these strategies yield is a kind of semantic realism that allows for certain claims (e.g., 'Muriatic acid contains the muriatic radical.') to be true. But the kind of realism with which I am concerned is a kind of entity realism, which concerns whether there is an empirical entity that corresponds in the right kind of way to Lavoisier's radical, *qua* theoretical entity. The suggestion that Lavoisier's term 'muriatic radical' partially denotes, in either Field's or McLeish's sense, is really an admission that there is no single empirical entity that corresponds to Lavoisier's radical in the right kind of way. This way of defending semantic realism, then, actually undermines, rather than supports,

entity realism about Lavoisier's radical. In that case, anti-realism is really the only reasonable option regarding Lavoisier's radical.

It could, however, be the case that other chemists had the resources to single out a particular empirical entity as the muriatic radical. I'll now argue that Berzelius was just such a chemist, in which case we ought to be realists about Berzelius's radical.

4.2 Realism About Berzelius's Radical

Berzelius's views on the nature of the two substances differ in a number of important respects from Lavoisier's views, and these differences make it reasonable to be a realist about Berzelius's radical. To begin with, Berzelius eventually came to the (correct) belief that muriatic acid is composed of hydrogen and chlorine, and that the latter is an element. As a result, for Berzelius, the muriatic radical is a component of muriatic acid, but not of oxymuriatic acid. Moreover, his views on hydracids gave him a principled way to distinguish the radical of muriatic acid, which he took to be chlorine, from the component common to all other hydracids, namely, hydrogen. And unlike Lavoisier, who held that the nature of the muriatic radical was, at the time, unknown, Berzelius identifies it with a substance that chemists could, in fact, isolate, namely, chlorine. If we are realists about chlorine, then, and if Berzelius's radical just is chlorine, then we ought to be realists about Berzelius's radical.

It may be objected that I'm being too charitable to Berzelius here. After all, Berzelius's views on acids were eventually discarded, and when it came to the so-called oxygenous acids, he was just as wrong as Lavoisier. Chemists today work with three concepts of acidity: (1) the concept of an *Arrhenius acid*, which is a substance that increases the concentration of H^+ ions in water, (2) the concept of a *Brønsted-Lowry acid*, which is a substance that is an H^+ donor, and (3) the concept of a *Lewis acid*, which is a substance that is an electron pair acceptor. None of these concepts of acidity give any sense to the question: which constituent of an acid is the radical? In that case, even if we ought to be realists about chlorine, perhaps our realism shouldn't extend to Berzelius's radical.

To be sure, it is certainly correct that current work on acidity has left behind the concept of a radical or acidifiable base. And Berzelius was quite wrong about oxygenous acids, which don't correspond to any category of acids studied by chemists today. But in some cases, it can be reasonable to

adopt a realist attitude toward some theoretical entity even if the theory in which that entity appears is not completely correct. And in Berzelius's case, there are two considerations that tell in favor of a realist attitude toward his radical.

First of all, as stated earlier, Berzelius's beliefs regarding the constitution of muriatic acid and oxymuriatic acid were by-and-large correct. And given that he could point to a sample of chlorine, he could surely identify it with a theoretical entity like his muriatic radical. We may object to the terminology that he used, but it's difficult to deny that he used that terminology to single out a unique kind of empirical entity, namely, chlorine. Moreover, there is no need for anything like partial denotation in the case of Berzelius's radical, and so semantic realism and entity realism line up.

Secondly, as Chang (2012a, 692) argues (though without discussing Berzelius's views), it's at least debatable that the notion of a hydracid prefigured two of our current conceptions of acidity. For Berzelius, hydrogen played an essential role in hydracids, and it also plays an essential role when it comes to both Arrhenius acids and Brønsted-Lowry acids. Berzelius's view implies that there is a class of acids, namely, hydracids, all of which contain hydrogen, and which differ from one another in terms of their other constituents, which can be simple or compound. This is basically correct when it comes to Arrhenius acids and Brønsted-Lowry acids, though it's not true of Lewis acids. The fact that Berzelius called the non-hydrogen constituents of these acids 'radicals' doesn't count as a reason to be an anti-realist about those constituents. And given that Berzelius, unlike Lavoisier, successfully pointed to something importantly right regarding the constitution of acids, it's reasonable to be a realist about his muriatic radical.

If realism about Berzelius's radical is reasonable, one might wonder whether there's a way to be a realist about Lavoisier's radical after all. More specifically, it might be the case that the reasons for identifying Berzelius's radical with chlorine can also be used in order to identify Lavoisier's radical with chlorine. To be sure, this would be a kind of retroactive identification, and one might be suspicious of it for that reason. But it's not clear that such a position is indefensible, and similar positions have been defended. To take one example, Jackman (1999) argues for a kind of semantic externalist view that he calls temporal externalism, according to which linguistic usage subsequent to some time t can be used in order to determine the referent of a term at t. Perhaps, then, we ought to conclude that Lavoisier's radical is chlorine.

Various positions under the heading of semantic externalism may give realists hope when it comes to some theoretical entities; but when it comes to Lavoisier's radical, the proper conclusion to draw is still anti-realism. When Putnam initially discussed his principle of charity, he emphasized that it involves assuming that speakers would accept "reasonable modifications" or "reasonable reformulations" of their descriptions (Putnam (1975, 275), (1978, 24)). As Bensaude-Vincent (1983, 69) has emphasized, the idea that oxygen is the acidifying principle "was not a secondary thesis in [Lavoisier's] system," and Davy's work "represented here a definite reversal of Lavoisier's ideas on muriatic acid." In a similar vein, it's not an exaggeration to claim that, if Lavoisier were to admit the existence of hydracids, this would constitute a complete abandonment of his theory of acidity, as opposed to a 'reasonable modification or reformulation.' Putnam is clear that charity can be overdone, and the historical details show that this is just such a case. Hence, a realist attitude toward Berzelius's radical doesn't imply that we ought to be realists about Lavoisier's radical as well.

4.3 A Retail Treatment of the Muriatic Radical(s)

We can now see how the case of the muriatic radical(s) requires a retail treatment as opposed to a wholesale one. I started by assuming a retail treatment of the radical, and distinguishing Lavoisier's radical from Berzelius's. I argued that we ought to be anti-realists about the former, and realists about the latter. This kind of selective realism is possible if and only if one adopts a retail treatment, as opposed to a wholesale treatment. And if I'm right that this sort of selective realism is the proper attitude to take toward these radicals, then we have a reason in favor of a retail treatment, and against a wholesale one.

At this stage of my argument, I've established, at best, that, when it comes to the case of the muriatic radical, a retail treatment is preferable to a wholesale one. But this, on its own, does not establish that retail treatments are, in general, preferable to wholesale ones. In the final section, I consider the benefits of employing retail treatments more generally.

5 Retail Realism and Retail Treatments

As I indicated earlier, I take it that retail realism represents a genuine step forward in the scientific realism debate, though I believe that it should be paired with retail, as opposed to wholesale, treatments of theoretical entities. I've attempted to illustrate the virtues of this combination of views when applied to the particular case of the muriatic radical. And at this point, I'll indicate why I take this combination of views to constitute an attractive position more generally, though what follows will inevitably fall short of a full defense.

To begin with, it's worth stating explicitly what this combination of views looks like more generally. As I've framed it, one of the central questions of the realism debate concerns the extent to which theoretical entities *qua* epistemic objects correspond to empirical entities that exist independently of our minds. A proponent of retail realism holds that we ought to attempt to answer such questions on a case-by-case basis, in terms of retail arguments. A proponent of retail treatments of theoretical entities holds that we ought to individuate such entities rather finely, so that distinct theories involve distinct theoretical entities. These two views complement one another rather nicely. The notion of a retail treatment provides a clear account of what it means to proceed on a case-by-case basis. And retail realism provides a framework for showing how a particular view regarding the individuation of theoretical entities can have important consequences for the realism debate. A proponent of both views, then, will be concerned with examining the extent to which particular theoretical entities in particular theories correspond to empirical entities.

In order to develop and defend this position a bit more, I'll close by considering two objections: one concerning the extent to which this position leads to a form of incommensurability, and one concerning the retail realist's desire to proceed on a case-by-case basis.

The first objection is that this position does, in fact, lead to a kind of incommensurability which many philosophers of science, especially realists, consider problematic. After all, I cited Kuhn as a proponent of retail treatments. Moreover, if we individuate theoretical entities as finely as we individuate theories, then we may seem forced to conclude that there's no sense in which distinct theories are about the same entities.

The second objection is that, although this position amounts to a combination of retail realism with retail treatments of theoretical entities, it is still

not 'retail' enough. Ideally, a retail realist would proceed on a case-by-case basis when determining whether a retail or wholesale treatment of a given theoretical entity is preferable, and would be free to choose a retail treatment in some cases, and a wholesale treatment in others. It's certainly possible that one may examine a case with the following characteristics: Retail realism, combined with a wholesale treatment, yields realism about a single theoretical entity, while retail realism, combined with a retail treatment, yields realism about all of a multitude of similar, but distinct, theoretical entities. It may be objected that a retail treatment of such a case would be ontologically profligate, perhaps even untenable, and that a wholesale treatment would therefore be desirable in the kind of case in question.

I believe that these two objections are, in fact, related, and so I'll attempt to answer both at once. To begin with, I have some sympathy with the second objection, but I believe that any perceived virtues of wholesale treatments are also virtues of retail treatments, but not vice versa. I've already illustrated a case in which it's desirable to adopt a retail treatment, as opposed to a wholesale one, which shows that retail treatments have virtues that wholesale treatments don't. As for the kind of case discussed in the previous paragraph, once one is clear about what is involved in the wholesale and retail treatments of such a case, the objection disappears. On the wholesale treatment, realism consists of the right kind of correspondence between a theoretical entity x and an empirical entity y. On the retail treatment, realism consists in the right kind of correspondence between each of a set of theoretical entities $x_1, \ldots, x_n$ and y. To be sure, the ontology involved in the retail treatment involves more entities than the ontology involved in the wholesale treatment. But these are theoretical entities, and given that they appear in distinct theories, there are important differences between them. In that case, it is not ontologically profligate to distinguish them, and retail treatments are actually preferable to wholesale treatments on the grounds that retail treatments do draw such distinctions. It may, of course, be ontologically profligate, or even untenable, to posit distinct empirical entities to which these theoretical entities correspond, but a retail treatment needn't be committed to such a consequence. And given that distinct theoretical entities can, and sometimes do, correspond to the same empirical entity, commensurability is at least possible, in which case the first objection disappears as well.

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