Hypothetical Entities and Realistic Interpretation:

The Case of the Muriatic Radical

Jonathon Hricko

Abstract: Scientific realists are committed to the claim that scientific discourse should be interpreted realistically, so that theoretical terms are understood as putatively referring expressions that have putative reference to empirical entities. In order to argue against realistic interpretation, I draw on an episode from the history of chemistry. One of the hypothetical entities of late 18th century chemistry was the muriatic radical, a hitherto unknown element that was thought to be a constituent of muriatic acid. I argue that the term 'muriatic radical' resists realistic interpretation, and that we should therefore refrain from interpreting discourse concerning hypothetical entities realistically.

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1. Introduction

When scientists put forward hypotheses, these hypotheses occasionally introduce entities that would inflate the ontology of their theories, and some of these entities are hypothetical entities. The sense of 'hypothetical entity' that I am interested in is given by the following rough guide.

> A hypothetical entity is a new (kind of) entity that a scientist puts forward as a (kind of) empirical entity in advance of decisive empirical reasons to do so.[1]

An empirical entity is an entity that exists in the natural world. 'Decisive empirical reasons' should be understood with reference to the consensus of the scientific community. The consensus need not be unanimous, but the reasons in question should be capable of eventually convincing the vast majority of the scientific community. For some examples of hypothetical entities, think of the planet hypothesized by John Adams and Urbain Le Verrier in the mid-19th century, or Antoine Lavoisier's caloric in the late 18th century, or the Higgs boson today. It should be emphasized that 'entity' in 'hypothetical entity' need not mean 'empirical entity.' Insofar as Lavoisier's caloric, for example, is a hypothetical entity, it is an entity in

[1]This rough guide is roughly in agreement with the account of hypothetical entities developed by Rynasiewicz, Steinert-Threlkeld, and Suri (2010, 10).

much the same way that an abstract or fictional entity is an entity.

Terms introduced to name hypothetical entities are what I will call *HE terms*, short for *hypothetical entity terms*. Here and throughout, I use the word 'name' in a slightly technical sense that doesn't entail that reference to an empirical entity is successful. This is important since some hypothetical entities, like caloric, are no longer thought to exist.

Hypothetical entities should not be equated with unobservable entities. To be sure, some hypothetical entities are unobservable, like Lavoisier's caloric. But some hypothetical entities, like that put forward by Adams and Le Verrier, are observable. And some unobservable entities, like the electron, are no longer hypothetical.

Hypothetical entities should also not be equated with theoretical entities. Following van Fraassen (1980, 14) and Chakravartty (2011, §1.1), I take it that a theoretical term is just a term that occurs in a scientific theory, as opposed to a term that names an unobservable entity. I classify an entity as a theoretical entity, then, if there is a theoretical term that names it. If theoretical entities are understood in this way, it is not a category mistake to classify an entity as theoretical, as van Fraassen (1980, 14) claims. HE terms are a proper subset of theoretical terms. Hypothetical entities, then, are a proper subset of theoretical entities.

Scientific realists are committed to a fairly concrete proposal when it comes to the semantics of discourse concerning hypothetical entities. In general, they hold that scientific discourse should be "interpreted ‘realistically,’ ” to use Richard Boyd’s terminology, as involving putatively referring expressions that have putative reference to empirical entities (1983, 45).[2] Following Boyd, I will use ‘realistic interpretation’ to refer to this idea. In this case, discourse concerning hypothetical entities should be interpreted realistically. Hence, on the realist view, Adams and Le Verrier were referring to Neptune before it was discovered. Lavoisier’s ‘caloric’ failed to refer to any empirical entity. And the jury is still out with regard to the Higgs boson, but scientists are either referring or failing to refer.

If the language of science is to be interpreted realistically, then the realist is committed to the following thesis when it comes to understanding discourse concerning hypothetical entities:

> Realism about Hypothetical Entities: HE terms should be understood as putatively referring expressions that have putative reference to empirical entities.

Moreover, the realist is committed to the following seemingly exhaustive trichotomy:

> T1 either an HE term, so understood, refers to an empirical entity;
>
> T2 or it fails to refer to an empirical entity;

[2]See also Psillos “semantic stance” (1999, xix).

T3 or it 'kind of' refers to that entity.[3]

If it can be shown that there are HE terms that don't fall within the taxonomy characterized by this trichotomy, then something is wrong with the realist account of realistic interpretation.

This commitment to realistic interpretation will be my target in what follows. In Section 2, I will argue that realistic interpretation does not yield an adequate framework for understanding discourse concerning hypothetical entities. In order to show why, I will discuss an episode from the history of chemistry involving the so-called muriatic radical, which, I will claim, resists realistic interpretation.

2. Reference and the Muriatic Radical

My goal in this section is to sketch the details of a case involving a hypothetical entity that doesn't fall within the realist's taxonomy. This is the case of the so-called muriatic radical, which was taken to be the unknown constituent of muriatic acid, the constitution of which was not well understood until the early years of the 19th century. After sketching some of the historical details, I will argue that there is no fact of the matter

[3](T3) includes, but is not limited to, views like Psillos' (1996, S313) approximate reference and Field's (1973) partial denotation, which are intermediate between full-blown reference and failure of reference.

about what empirical entity, if any, 'muriatic radical' bears a referential relation to.

A convenient starting point for the story of the muriatic radical is Antoine Lavoisier's theory of acidity. Lavoisier develops his theory in a number of papers,[4] but it reached maturity at least by the time he wrote his *Traité élémentaire de Chimie*, originally published in 1789, and so I will focus on his formulation of it in that work.[5]

Lavoisier begins chapter five of part one of the *Traité* with a discussion of a number of experiments. These experiments show how three combustible bodies combine with oxygen to form acids. A combustible body for Lavoisier is just "a body which possesses the power of decomposing oxygen gas, by attracting the oxygen from the caloric with which it was combined" (1802, 111). The combustible bodies that Lavoisier employs in these experiments are phosphorus, sulphur, and carbon, which, he claims, when combined with oxygen, form phosphoric acid, sulphuric acid, and carbonic acid, respectively. He labels the process by which these bodies are converted into acids "oxygenation," and writes of "oxygenating"

[4]See, for example, Lavoisier (1776) and Lavoisier (1778).

[5]In what follows, my quotations are drawn from Robert Kerr's 1802 translation.

a combustible body like phosphorus in order to covert it into an incombustible acid (110–1).

Although Lavoisier could employ more examples, he generalizes to a theory of acidity from the three mentioned above.

> By these [three examples], it may be clearly seen, that oxygen is an element common to them all, and which constitutes or produces their acidity; and that they differ from each other, according to the several natures of the oxygenated or acidified substances. 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. (114)

There were a number of acids in Lavoisier's day that were yet to be decomposed, and so one could not yet prove that they contain oxygen. Among these acids was the so-called muriatic acid. Lavoisier was nonetheless fairly certain that this acid could be accommodated by his theory of acidity. That is to say, he hypothesized that it is made up of oxygen, the acidifying principle, combined with some unknown acidifiable base or radical, which he called the 'muriatic radical.' Lavoisier discusses the muriatic radical in the following 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* . . . (121–2)

Based on Lavoisier's discussion here, we can see that the muriatic radical is a hypothetical entity according to the rough guide in Section 1. Theoretical considerations lead Lavoisier to put forward this entity as an empirical entity, but those considerations were less than decisive.

Lavoisier was also concerned with another as-yet undecomposed acid, which he thought to be related to muriatic acid. This is the acid he calls 'oxygenated muriatic acid,' and what others call 'oxymuriatic acid.'[6] Lavoisier held that two different acids can have the same constituent elements, and that what makes them different is the different proportions of those elements that the acids contain. For example, he believed that both sulphurous acid and sulphuric acid contain nothing but sulphur and oxygen. What makes them different acids is that the former is "under-saturated with oxygen," while the latter is "completely saturated" (117–8). In the same way, Lavoisier held that oxymuriatic acid results from a combination of muriatic acid and oxygen, in which case oxymuriatic acid contains the muriatic radical as well (123–124). To put the point another

[6]For Lavoisier's terminology, see Lavoisier (1802, 123–124). For the alternative terminology, see, for example, Davy (1810).

way, muriatic acid is "under-saturated with oxygen," while oxymuriatic acid is "completely saturated," though, to be sure, both contain the muriatic radical.

In 1811, Humphry Davy successfully decomposed muriatic acid (1811). The results were somewhat surprising. As it turns out, this acid contains no oxygen, so Lavoisier's theory was wrong—oxygen is not the acidifying principle. Muriatic acid actually contains hydrogen and oxymuriatic acid as its constituents, whereas before, it was thought that muriatic acid is a constituent of oxymuriatic acid. Since oxymuriatic acid contains neither oxygen nor muriatic acid, Davy proposed a new name for it: chlorine (1811, 32). Muriatic acid, then, is what we now call hydrochloric acid (HCl).

The history that I've sketched here spells trouble for the realist account. If one adopts that account, it's not at all clear how one would classify the muriatic radical. To begin with, there are good reasons to think that 'muriatic radical' refers to hydrogen. Lavoisier's English translator, Robert Kerr, notes Christoph Girtanner's claim that hydrogen is the muriatic radical (Lavoisier 1802, 122). This was about ten years before Davy's work, but Davy himself claims that "muriatic acid may be considered as having hydrogene for its basis, and oxymuriatic acid for its acidifying principle" (1810, 243). Davy was not alone in this—John Dalton writes that Davy's "notion agrees so far with [his], as to make hydrogen the base of muriatic acid" (1808, 552). In a later paper, Davy notes some analogies between oxygen and chlorine, which provide support for this claim. For example, when one uses a Voltaic battery to decompose a substance, chlorine, oxygen, and acid matter appear at the positive pole, while hydrogen and alkaline matter appear at the negative pole (Davy 1826, 398). If chlorine is analogous to what Lavoisier thought to be the acidifying principle, then this leaves hydrogen as the base, in which case 'muriatic radical' may be taken to refer to hydrogen.

There are also good reasons to think that 'muriatic radical' refers to chlorine. Although the analogies that Davy mentions suggest that chlorine is the acidifying principle in muriatic acid, chemistry textbooks at the time claim that hydrogen is also a principle of acidity. For example, in John Webster's 1826 textbook, one finds the following:

> [O]xygen is not essential to the acidity of a compound, for some bodies are rendered acid by union with chlorine, others by hydrogen; and the theory of Lavoisier which considered oxygen as the essential principle of acidity, and in conformity to which its present name was assigned to it can no longer be received as correct. (1826, 88)

Hence, if one takes hydrogen to be the acidifying principle, that leaves chlorine as the base or radical of muriatic acid. Some writers have, indeed, taken chlorine to be the muriatic radical. In the later years of the 19th century, Josiah Parsons Cooke, a professor of chemistry and mineralogy at Harvard, identified the muriatic radical with chlorine (1889, 741). And more recently, Bernadette Bensaude-Vincent has made a similar identification (1983, 69–70).

Finally, there are good reasons for thinking that 'muriatic radical' refers to nothing at all. To see this, recall that Lavoisier held that muriatic acid is a constituent of oxymuriatic acid. So if, by 'muriatic radical,' Lavoisier meant something like 'that element which combines with oxygen (the acidifying principle) to form muriatic acid, which, in turn, combines with oxygen to form oxymuriatic acid,' there is nothing in the world that corresponds to this description. Moreover, there are good reasons for thinking that 'muriatic acid' lacks a referent because there is no principle of acidity. Based on our current understanding of the nature of acids, neither oxygen nor hydrogen nor chlorine is a principle of acidity. In this case, it's pointless to attempt to determine which constituent of muriatic acid is the base or radical, since we've rejected the view that acids are composed of an acidifying principle and an acidifiable base. This kind of reasoning is perhaps what leads Hasok Chang to claim that the muriatic radical does not exist (2011, 417), in which case 'muriatic radical' would altogether fail to refer to an empirical entity.[7]

We can now examine T1–T3 in light of these reasons. First of all, if

[7] See also Michela Massimi (2009, 114), who attributes this view to Chang and Georgette Taylor.

‘muriatic radical’ falls under T1, then it refers to an empirical entity. In this case, it would refer to either hydrogen or chlorine. But the reasons on both sides are equally compelling. Insofar as chlorine is the acidifying principle, hydrogen is the radical. And insofar as hydrogen is the acidifying principle, chlorine is the radical. It’s not clear what fact could come to light that would tell us which one really is the radical, especially given the fact that we’ve rejected Lavoisier’s theory of acidity long ago. In this case, ‘muriatic radical’ would lack a determinate referent, and would therefore fall short of successful reference to an empirical entity.

Secondly, if ‘muriatic radical’ falls under T2, then it fails to refer to an empirical entity. Insofar as we no longer accept a theory of acidity according to which an acid is composed of an acidifying principle combined with an acidifiable base, this would seem to be the natural conclusion. However, it may be too uncharitable to demand that Lavoisier be in possession of one of the (by our lights) correct theories of acidity in order to successfully refer. Moreover, the present case is not analogous to clear-cut cases of non-referring terms. In the present case, there are two empirical entities that are good candidates for what Lavoisier could have been referring to, namely, hydrogen and chlorine. In this case, there isn’t a decisive reason to conclude that ‘muriatic radical’ failed altogether to refer to an empirical entity.

This leaves T3 as the only option. If ‘muriatic radical’ falls under T3, then it approximately refers to or partially denotes some entity or entities.

In this case, it may be natural to suppose that 'muriatic radical' approximately refers to and/or partially denotes both hydrogen and chlorine. Both of these entities seem to satisfy Psillos' (1996, S313) criteria for approximate reference. Both share some of the properties ascribed to the muriatic radical. For example, both have the property that they enter into the composition of muriatic acid. Moreover, both are causally responsible for the phenomena that the muriatic radical was supposed to be causally responsible for, namely the behavior of muriatic acid. Similar reasoning would entail that 'muriatic radical' partially denotes both hydrogen and chlorine.

The problem with taking this option is that there are still strong reasons that suggest that 'muriatic radical' never referred to anything, and bringing in the notions of approximate reference and partial denotation does nothing to address these reasons. As brilliant as he was, Lavoisier was simply wrong about the nature of acids—oxygen is not the principle of acidity. Moreover, Lavoisier, along with other chemists at the time, thought that the muriatic radical combined with oxygen to form oxygenated muriatic acid, which turned out to be the element chlorine. The notions of approximate reference and partial denotation can help us to sidestep the difficulty of assigning just one referent to 'muriatic radical.' But those notions are unsatisfying insofar as they leave the strong suspicion that 'muriatic radical' lacks a referent unaddressed. To put this another way, it's not possible for a term to approximately refer to or partially denote two entities and zero entities simultaneously.

One may get the sense that one option has to be right here, and it's just a matter of figuring out which one it is. But any way of deciding the issue would be artificial in some sense, and would leave some nagging concerns unaddressed. The case of the muriatic radical therefore poses a strong challenge to the realist, insofar as it can't be happily classified according to the realist's proposed taxonomy. The realist may admit the challenge, and devote her efforts to answering it. But given that it's not clear what kind of fact could possibly come to light that would decide this issue, a more natural conclusion to draw is that there is no fact of the matter about what, if anything, 'muriatic radical' refers to. And if this is the case, then the realist view is flawed—the notion of realistic interpretation cannot make sense of scientific discourse concerning hypothetical entities like the muriatic radical.[8]

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[8] Acknowledgements.

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