

Experimental Individuation and Retail Arguments

Ruey-Lin Chen

Department of Philosophy, National Chung Cheng University, Taiwan

Jonathon Hricko

Education Center for Humanities and Social Sciences, National Yang-Ming University,
Taiwan

Abstract: Magnus and Callender (2004) argue that we ought to focus on retail arguments, which are arguments regarding the existence of particular kinds of theoretical entities, as opposed to theoretical entities in general. However, *scientists* are the ones who put forward retail arguments, and it's unclear how *philosophers* can engage with such arguments. We argue that philosophers can engage with retail arguments by providing criteria that they must satisfy in order to demonstrate the existence of theoretical entities. We put forward experimental individuation as such a criterion—when scientists experimentally individuate an entity, a realist conclusion about that entity is warranted.

Word Count: 4983

1. Introduction

Magnus and Callender argue that we ought to abandon “wholesale arguments,” which are “arguments about all or most of the entities posited in our best scientific theories” (2004, 321). Instead, we ought to embrace “retail arguments,” which are “arguments about specific kinds of things such as neutrinos, for instance” (2004, 321). This shift in focus rules out standard scientific realism as well as various antirealist positions, and in Section 2, we’ll argue that Magnus and Callender’s position is preferable to these other positions.

However, we recognize that philosophers who choose to abandon wholesale arguments in favor of retail arguments face a potential problem. Dicken (2013) has argued that such philosophers will merely end up repeating the retail arguments that scientists offer. In that case, the turn to retail arguments may entail that no distinctively philosophical work remains to be done. In Section 3, we’ll argue that this is not the case. Not all retail arguments successfully demonstrate the existence of theoretical entities, and it can take some philosophical work to distinguish the ones that do from the ones that don’t.

In Section 4, we’ll put forward a criterion for doing so, which we take from Chen’s (2016) work on experimental individuation. Chen suggests that “[i]f 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” (2016, 365). We’ll argue that retail arguments that demonstrate the experimental individuation of a theoretical entity succeed in showing that realism about that entity is warranted.

We'll draw on three examples throughout the paper: Lavoisier's oxygen theory of acidity, J. J. Thomson's work on cathode rays, and Davy's discovery of potassium. We'll conclude, in Section 5, by applying our criterion to these three cases, with the result that the upshot of a retail argument can be either realism, antirealism, or skepticism regarding the existence of a particular kind of theoretical entity.

2. The Turn to Retail Arguments

We'll now introduce Magnus and Callender's position in a bit more detail, and indicate why we take it to be preferable to standard scientific realism (SSR) and antirealism. SSR is a position regarding theories in general—the success of our best theories warrants the claim that they are at least approximately true, as well as the claim that the theoretical entities that they posit exist. Antirealist positions come in a number of different forms, but they all typically endorse claims about theories in general, and deny that success warrants the two claims endorsed by proponents of SSR.

According to Magnus and Callender, there is something that all of these positions have in common, namely, their proponents attempt to support these positions by engaging in wholesale arguments. They focus on two examples of such arguments. First of all, there is the no-miracles argument, according to which the success of our best theories would be a miracle if those theories weren't at least approximately true. Secondly, there is the pessimistic meta-induction, which uses past successful-but-false theories as an inductive basis for concluding that our current successful theories are false as well. The no-miracles argument is taken to support “[w]holesale realism,” which “seeks to explain

the success of science in general”; and the pessimistic meta-induction is taken to support “wholesale anti-realism,” which “seeks to explain the history of science in general” (2004, 321). However, Magnus and Callender argue that these arguments, and wholesale arguments in general, ought to be abandoned. This is because they embody the base rate fallacy, since they don’t take into account the base rate probability of any successful theory being true or false. For this reason, they maintain that wholesale realism and wholesale antirealism ought to be abandoned as well.

Magnus and Callender propose that we ought to replace wholesale arguments with retail arguments. Unlike wholesale arguments, the scope of a retail argument is restricted to a particular theory and/or a particular kind of theoretical entity. By shifting the focus from theories in general to theories in particular, philosophers can *dissolve* the traditional realism debate, with the result that “realism and anti-realism are options to be exercised sometimes here and sometimes there” (2004, 337). This, in turn, opens up the possibility that “[t]here may be good reasons to be a realist about neutrinos, an anti-realist about top quarks, and so on” (2004, 333).

In order to show why this possibility represents an improvement over SSR and antirealism, we’ll now consider a case from the history of chemistry. This case concerns the composition of hydrochloric acid. Scheele was the first to decompose this acid, which he called “acid of salt,” and he identified its constituent substances as phlogiston and “dephlogisticated acid of salt” (1774/1931). However, it was a matter of some controversy whether he had succeeded in decomposing hydrochloric acid. According to Lavoisier’s oxygen theory of acidity, all acids are composed of oxygen (the principle of acidity) and a radical, which can be either a simple substance or a compound (1789/1965,

65, 115). Neither Scheele nor any other chemist had been able to extract the oxygen from hydrochloric acid, which Lavoisier called “muriatic acid.” And so Lavoisier held that it remained undecomposed, and, in accordance with his theory, he hypothesized that it must contain oxygen combined with what he called “the muriatic radical” (1789/1965, 71-72). As for Scheele’s dephlogisticated acid of salt, Lavoisier held that it is a compound of muriatic acid and oxygen, which he called “oxygenated muriatic acid” (1789/1965, 73). Some years later, Davy argued that Scheele was correct, while Lavoisier was in error (1810, 236-37). On Davy’s view, muriatic acid is composed of hydrogen and what he calls “oxymuriatic acid,” which is what Lavoisier called “oxygenated muriatic acid,” and what Scheele called “dephlogisticated acid of salt.” Davy later went on to argue for the elementary nature of this latter substance, and proposed a new name for it: “Chlorine” (1811, 32). His approval of Scheele stems from the fact that Davy, like a number of latter-day phlogiston theorists, identified hydrogen with phlogiston.¹ And the claim that hydrochloric acid is made up of hydrogen and dephlogisticated acid of salt, even if terminologically problematic, is essentially correct. Lavoisier, however, was in error since this acid contains no oxygen, thus falsifying his oxygen theory of acidity.

Proponents of SSR, impressed by narratives of the Chemical Revolution according to which Lavoisier’s oxygen theory defeated the phlogiston theory, are often explicit that their realism applies to the oxygen theory but not to the phlogiston theory.² But in that case, SSR entails the implausible conclusion that Lavoisier’s muriatic radical exists, while Scheele’s dephlogisticated acid of salt does not. It seems much better to

¹ See, e.g., Kirwan (1789, 4-5).

² See, e.g., Hardin and Rosenberg (1982, 610) and Psillos (1999, 291).

conclude that Lavoisier's muriatic radical doesn't exist, while Scheele's dephlogisticated acid of salt does.

Antirealism, at least of the Kuhnian variety, fares no better. Those influenced by Kuhn's (1962/1996) views regarding incommensurability would claim that theoretical entities conceptualized by rival theories should be treated as different entities. However, chemists working in the late eighteenth and early nineteenth centuries shared a set of operations for producing the substance that was variously known as dephlogisticated acid of salt, oxymuriatic acid, and chlorine. It's therefore implausible to maintain that, in light of the fact that these chemists held different theories, they were working with distinct theoretical entities. A trans-theoretical view of the substance that came to be known as chlorine is therefore preferable.

By abandoning wholesale arguments in favor of retail arguments, we can sidestep these difficulties, and simply adopt realism about chlorine (whatever it was called and however it was conceptualized) and antirealism about Lavoisier's muriatic radical. That said, by trading wholesale arguments for retail arguments, we face another difficulty, to which we'll now turn.

3. Can Philosophers Engage with Retail Arguments?

Dicken (2013) has objected that those who abandon wholesale arguments in favor of retail arguments face a serious difficulty. In short, once one does so, it's not clear that any "distinctively philosophical" issues remain to be addressed (2013, 564). Scientists are generally the ones who put forward retail arguments. And if the turn to retail arguments

amounts to merely repeating arguments scientists have offered first, then perhaps nothing distinctively philosophical remains to be done. Our goal in the remainder of the paper is to provide a way of engaging with retail arguments that is distinctively philosophical, and to thereby answer Dicken's objection.

We'll start by considering how scientists demonstrate the existence of theoretical entities, and so we'll now introduce another case from the history of science. This case concerns Thomson's work on cathode rays and his determination of the mass-to-charge ratio (m/e) of the electron. According to the official website of the Nobel Prize, it was because of this work that Thomson "received the Nobel Prize in 1906 for the discovery of the electron, the first elementary particle."³ Thomson (1897, 1906/1967) hypothesized that cathode rays are currents of "carriers of negative electricity" or "corpuscles"—what we now know as electrons.⁴ His hypothesis was not only about the nature of cathode rays, but also about the interaction among cathode rays and other theoretical entities such as electrostatic fields and electrons. In order to determine the mass-to-charge ratio, he measured the deflection of cathode rays passing through an electrostatic field, the strength of the electrostatic field, and other related magnitudes. He interpreted the value that he obtained for m/e in light of his hypothesis, and his experimental results confirmed that hypothesis.

³ Retrieved January 27, 2016 from

<http://www.nobelprize.org/educational/physics/vacuum/experiment-1.html>. See also Harré (2002) and Whittaker (1989).

⁴ For the identification of Thomson's carriers with electrons, see the reprint of Thomson (1897) in Magie (1969), in which Magie makes the identification.

However, one might ask how it's possible to infer from Thomson's experimental confirmation of his hypothesis to the claim that he had thereby demonstrated the existence of the electron. Philosophers can engage with such a question. And regardless of the answers they provide, they must at least defend those answers by invoking some kind of criterion for concluding that the evidence that scientists have offered does or does not constitute a demonstration of the existence of a given entity. To take one example of such a criterion, Hacking (1983, 23) suggests manipulation: "if you can spray them then they are real." While Thomson manipulated cathode rays, he did not manipulate electrons, and so, according to Hacking's criterion, Thomson did not offer evidence strong enough to demonstrate the existence of electrons.

The important point, for our purposes, is that providing a criterion for granting the reality of a theoretical entity, and determining whether the evidence that scientists have offered satisfies that criterion, constitutes a way for philosophers to engage with retail arguments. Scientists may be the ones who initially put forward retail arguments. But it is a distinctively philosophical task to determine a criterion that can distinguish those retail arguments that demonstrate the existence of a theoretical entity from those that do not. We thus have a way of answering Dicken's objection, provided that, by invoking such a criterion, we are not thereby turning back to wholesale arguments. In the next section, we'll introduce our criterion and argue that applying it does not amount to a wholesale argument.

4. Ontological Commitment and Experimental Individuation

Our proposed criterion for granting the reality of theoretical entities is experimental individuation. A retail argument that demonstrates the experimental individuation of an entity is a good argument for realism about that entity.

Individuation and ontological commitment are connected. When scientists are ontologically committed to the theoretical entities that they posit, this commitment involves not just a belief that the entities exist, but also a responsibility to demonstrate their existence. Demonstrating the existence of a posited entity requires scientists to find an individual instance or sample of that entity, and if a scientist posits a theoretical entity without individuating it, then her ontological commitment is empty.

How do scientists individuate theoretical entities? Answering this question requires us to distinguish *theoretical individuation* from *experimental individuation*. Scientists theoretically individuate an entity if, in the course of theorizing, they describe a set of properties and behaviors of a posited entity by which they can identify it and distinguish it from other entities. However, these descriptions by which scientists theoretically individuate entities require evidence. Scientists can offer evidence for the existence of a theoretical entity if they produce an instance or sample of such an entity by performing an experiment. In doing so, they individuate an entity experimentally.⁵

The relationship between theoretical individuation and experimental individuation is much the same as the relationship between theory and experiment more generally.

⁵ Scientists may also individuate an entity *observationally*, by observing an instance or sample of such an entity. Since observation is itself a complex issue, and since participants in the realism debate rarely question the existence of entities that scientists have observed, we will not discuss observational individuation here.

Various worries about the theory-ladenness of experimentation are relevant here. If a theoretical hypothesis yields a prediction regarding some experimental result, the result may be interpreted in light of the hypothesis. Moreover, since a theoretical hypothesis may involve two or more theoretical entities and their interactions, it can be difficult to show that an experiment produces an instance or sample of the target entity, i.e., that it experimentally individuates that entity. And it can be difficult to judge whether an experiment produces a real individual, as opposed to a mere phenomenon that results from experimental apparatuses and their interactions with experimented objects. For these reasons, a criterion of experimental individuation that is sufficiently independent of theoretical interpretation is needed.

Is there such a criterion for experimental individuation? One candidate is Hacking's manipulation criterion, which we mentioned in Section 3. However, since experimenters can manipulate not just real individuals, but also mere phenomena, manipulation cannot singly serve as the criterion of experimental individuation. Chen (2016) takes Hacking's criterion of manipulation, along with two other criteria, namely, separation and maintenance of structural unity, as jointly constituting a necessary and sufficient condition for the experimental individuation of a theoretical entity. In short, experiments that produce individuals are experiments that separate individuals from their surrounding environment, manipulate them, and maintain their structural unity throughout the process. Importantly, Chen's further conditions ensure that the manipulated object is a real individual as opposed to a mere phenomenon. We take Chen's criteria to offer a satisfactory account of experimental individuation. In Section 5, we'll illustrate his criteria in terms of three retail arguments from the history of science,

and thereby provide some support for our claim that his criteria are satisfactory.

For now, we wish to emphasize two points. First of all, experimental individuation is our proposed criterion for determining whether a retail argument successfully demonstrates the existence of some theoretical entity—it succeeds if it demonstrates the experimental individuation of that entity. Secondly, Chen’s three criteria provide an adequate account of what experimental individuation requires.

Before moving on, we’ll discuss two potential problems with this proposal. First of all, some theoretical entities, like the chemical substances named by mass terms like ‘water,’ ‘phlogiston,’ and ‘oxygen,’ are paradigm cases of non-individuals. It’s therefore not immediately obvious how we can appeal to the notion of experimental individuation when it comes to such entities. We propose to do so by considering the experimental individuation of *samples* of such substances, as we’ll illustrate in Section 5.1, in terms of Davy’s discovery of potassium. Since samples count as individuals, our criterion is applicable to cases involving non-individuals like chemical substances.

Secondly, there’s the issue as to whether the application of our criterion amounts to a kind of wholesale argument. Whether a given retail argument demonstrates the experimental individuation of some theoretical entity is a local matter, grounded in the details of that argument. In contrast, wholesale arguments are not grounded in such local matters. Instead, they rely on claims regarding populations of theories in general, and it is for this reason that they embody the base rate fallacy. We’ve consciously avoided reasoning that may lead to the base rate fallacy. For example, we haven’t argued that the success of our best theories would be a miracle unless the entities they posit can be experimentally individuated. For these reasons, the application of our criterion to retail

arguments does not amount to a kind of wholesale argument. And in that case, we've provided a way of answering Dicken's objection, since our criterion provides a way for philosophers to engage with retail arguments.

5. Application of the Criterion to Three Retail Arguments

Our goal at this point is to show how one can use the criterion we've proposed in order to engage with retail arguments regarding the existence of particular kinds of theoretical entities. We'll discuss three cases: Davy's potassium, Lavoisier's muriatic radical, and Thomson's electron.

5.1 A Realist Conclusion Regarding Davy's Potassium

To begin with, we'll argue that Davy demonstrates the experimental individuation of potassium, and thereby provides us with a successful retail argument for realism about that substance.

Davy first isolated potassium by decomposing potash, which he did by means of electrolysis (1808, 4-5). He was the first to decompose potash, though for some time, chemists suspected it to be a compound.⁶ Davy acted on a small piece of moistened potash with a Voltaic battery. As a result, at the negative surface of the battery Davy observed the appearance of "small globules having a high metallic lustre, and being precisely similar in visible characters to quicksilver" (1808, 5). In the lecture in which he

⁶ See, e.g., Lavoisier (1965/1789, 156).

reports these results, Davy goes on to write: “These globules, numerous experiments soon shewed to be the substance I was in search of, and a peculiar inflammable principle the basis of potash” (1808, 5). And later in the lecture, he proposes the name “Potasium [sic]” for the basis of potash (1808, 32).

While this experiment, on its own, does not demonstrate the experimental individuation of a sample of potassium, subsequent experiments that Davy conducted do, and he shows that potassium satisfies all three of Chen’s criteria. First of all, there is Chen’s separation condition: scientists must separate the entities that they produce “from their environments” (2016, 348), and “from the experimental instruments that may have helped produce [them]” (2016, 365). In order to determine whether his results depended on the platinum instruments that he used, Davy performed a number of experiments using a variety of other materials, including copper, silver, and gold (1808, 5). And in order to determine whether his results depended on the fact that he conducted his experiments in the open atmosphere, he performed similar experiments in a vacuum (1808, 5). In all of these cases, he obtained the same results. These experiments collectively show that Davy had separated potassium from its surrounding environment (including the atmosphere and the other components of potash), and from the instruments that he used, thereby satisfying Chen’s separation condition.

Secondly, there is Chen’s condition regarding the maintenance of structural unity. Chen understands structural unity as the idea that “the components of an individual are structured into a whole in some specific manner” (2016, 358). Davy encountered a number of difficulties when it came to maintaining the structural unity of the globules of potassium that he had produced because “they acted more or less upon almost every body

to which they were exposed” (1808, 10). One of the first things Davy notes about the globules is that they did not last long—the ones that did not explode immediately after forming soon lost their metallic luster and became “covered by a white film” (1808, 5). Davy identifies this film as pure potash, and explains how it attracts moisture from the atmosphere, converting the globule into a saturated solution of potash (1808, 7).

Eventually, Davy discovered one substance on which potassium did not have much of an effect, namely, recently distilled naphtha (1808, 10). He used that fluid to preserve globules of potassium, and he was able to examine the properties of potassium in the atmosphere by covering the globules with a thin film of naphtha. This method allowed Davy to maintain the structural unity of potassium, thus satisfying Chen’s condition.

Thirdly, there is Chen’s manipulation condition. Chen understands this condition in terms of the “instrumental use” of an object “to investigate other phenomena of nature” (2016, 358). Towards the end of the lecture in which he reports the electrolytic decomposition of potash, Davy conjectures that the globules of potassium he isolated “will undoubtedly prove powerful agents for analysis; and having an affinity for oxygen [sic] stronger than any other known substances, they may possibly supersede the application of electricity to some of the undecomposed bodies” (1808, 44). Making good on this conjecture would amount to showing that chemists can use potassium to decompose previously undecomposed substances, thereby satisfying Chen’s manipulation condition. And in the following year, Davy made good on this conjecture by using potassium to extract the oxygen from a previously undecomposed substance, namely, boracic acid, thereby decomposing it (1809, 76-77).

In sum, Davy shows that samples of potassium satisfy all three of Chen’s criteria.

And by demonstrating the experimental individuation of these samples, Davy presents us with a successful retail argument for realism about potassium.

5.2 An Antirealist Conclusion Regarding Lavoisier's Muriatic Radical

We'll now argue that Davy shows why the experimental individuation of Lavoisier's muriatic radical is not possible, and thereby provides us with a successful retail argument for antirealism about Lavoisier's radical.

As we discussed in Section 2, Lavoisier hypothesized that hydrochloric acid, which he called muriatic acid, is composed of oxygen and a hypothetical substance that he called the muriatic radical. He thereby theoretically individuated the muriatic radical as that substance which combines with oxygen to form muriatic acid, which, in turn, is converted into oxymuriatic acid (i.e., chlorine) by means of combining with even more oxygen. But as we emphasized in Section 4, theoretical individuation is a mere belief, and beliefs require evidence.

Davy (1810, 235-36) provides a retail argument that demonstrates that the experimental individuation of Lavoisier's radical is not possible. He emphasizes the results of various experiments that he and other chemists performed, which show that oxymuriatic acid combines with hydrogen to form muriatic acid. And he goes on to discuss those experiments that seem to show the decomposition of oxymuriatic acid into oxygen and muriatic acid. Davy observes that in these experiments, water is always present. And he concludes that the oxygen that such experiments produce results from the decomposition of the water, not from the decomposition of oxymuriatic acid, which has

not been demonstrated. If oxymuriatic acid doesn't contain oxygen, and muriatic acid contains oxymuriatic acid and hydrogen, then muriatic acid doesn't contain oxygen either. To adopt Davy's later terminology, the only components of muriatic acid are hydrogen and chlorine. Experimentally individuating the muriatic radical would involve separating it from the oxygen with which it combines to form muriatic acid and oxymuriatic acid. And since Davy showed that this is not possible, he gives us a successful retail argument for antirealism about Lavoisier's radical.

5.3 A Skeptical Conclusion Regarding Thomson's Electron

Finally, we'll argue that Thomson neither demonstrates the experimental individuation of the electron, nor shows that it is impossible. Hence, we have an example of an inconclusive retail argument. The proper response to such an argument is skepticism regarding the entity in question, at least until there is a conclusive retail argument regarding the existence of that entity.

Thomson (1897) designed a new type of cathode ray tube (figure 1) to perform a deflection experiment.

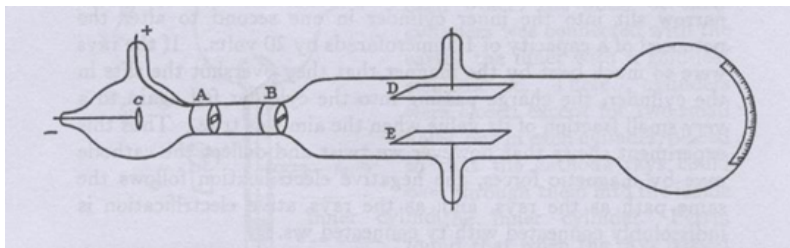


Figure 1. Thomson's cathode ray tube in 1897. Reproduced from Thomson 1969, 586.

This tube contains a cathode *C*, a cylindrical anode *A* with a slit, a cylindrical metal ring *B* with a slit, and a pair of plates *D* and *E* that produce an electrostatic field. A cathode ray is produced when the cathode discharges, and the ray passes through the slits in *A* and *B* before passing through the electrostatic field produced by *D* and *E*. Thomson's goal was to determine whether the ray would be deflected in the field, and to thereby determine the composition of cathode rays. The basic idea was that, if cathode rays were made of ethereal waves, the rays would not be deflected by an electrostatic field; if, however, the rays were made up of negatively electrified bodies, then the rays would be deflected by an electrostatic field.

Thomson's thought was that a cathode would produce both electric currents and cathode rays when discharging, and that, in order to determine the composition of cathode rays, it would be necessary to eliminate the electric currents and experiment with purified cathode rays. Purification is the function of the cylindrical metal ring *B*, which absorbs the electric currents leaked from *A* and thus ensures that the ray passing through *B* is pure. Thomson found that the purified cathode ray was deflected when it passed between the plates *D* and *E*, thus confirming that cathode rays are made up of negatively electrified bodies.

While Thomson satisfies Chen's criteria when it comes to cathode rays, he didn't thereby experimentally individuate the electrons that make them up. Thomson succeeded in *separating* cathode rays from currents; purifying them with the metal ring *B*, and thus *maintaining their structural unity*; and *manipulating* them by deflecting them with an electrostatic field. According to Chen's criteria, one can say that Thomson experimentally individuated cathode rays and demonstrated that they are currents of

negative electricity. But Thomson *presupposed* rather than demonstrated that the currents consist of electrons. He did not demonstrate the existence of electrons, because he did not experimentally individuate them. Hence, the proper response to the retail argument that Thomson gives us is neither realism nor antirealism, but rather skepticism regarding the existence of electrons, at least until there is a conclusive retail argument.

6. Conclusion

Our goal in this paper has been to provide a way for philosophers to engage with retail arguments, and thereby show that, even if we dissolve the traditional realism debate, there is still philosophical work to be done. We've put forward the criterion of experimental individuation in order to determine whether a given retail argument demonstrates the existence of a particular kind of theoretical entity. And we've applied that criterion to three cases, with the result that the upshot of a retail argument can be either realism, antirealism, or skepticism regarding the existence of a particular kind of theoretical entity.

References

Chen, Ruey-Lin (2016). "Experimental Realization of Individuality." In *Individuals Across the Sciences*, ed. Thomas Pradeu and Alexandre Guay, 348-70. New York: Oxford University Press.

Davy, Humphry (1808). "The Bakerian Lecture [for 1807], on Some New Phenomena of Chemical Changes Produced by Electricity, Particularly the Decomposition of the Fixed Alkalies, and the Exhibition of the New Substances Which Constitute Their Bases; And on the General Nature of Alkaline Bodies." *Philosophical Transactions of the Royal Society of London* 98: 1-44.

— (1809). "The Bakerian Lecture [for 1808]: An Account of Some New Analytical Researches on the Nature of Certain Bodies, Particularly the Alkalies, Phosphorus, Sulphur, Carbonaceous Matter, and the Acids Hitherto Undecomposed; With Some General Observations on Chemical Theory." *Philosophical Transactions of the Royal Society of London* 99: 39-104.

— (1810). Researches on the Oxymuriatic Acid, Its Nature and Combinations; And on the Elements of the Muriatic Acid. With Some Experiments on Sulphur and Phosphorus, Made in the Laboratory of the Royal Institution. *Philosophical Transactions of the Royal Society of London* 100: 231-57.

— (1811). The Bakerian Lecture [for 1810]: On Some of the Combinations of Oxymuriatic Gas and Oxygene, and on the Chemical Relations of These Principles, to Inflammable Bodies. *Philosophical Transactions of the Royal Society of London* 101: 1-35.

Dicken, Paul (2013). “Normativity, the Base-Rate Fallacy, and Some Problems for Retail Realism.” *Studies In History and Philosophy of Science* 44(4): 563-70.

Hacking, Ian (1983). *Representing and Intervening*. Cambridge: Cambridge University Press.

Hardin, Clyde L. and Alexander Rosenberg (1982). In Defense of Convergent Realism. *Philosophy of Science* 49(4): 604-15.

Harré, Rom (2002). *Great Scientific Experiments: Twenty Experiments that Changed our View of the World*. New York: Dover.

Kirwan, Richard (1789). *An Essay on Phlogiston and the Constitution of Acids*. 2nd ed. London: J. Johnson.

Kuhn, Thomas S. (1962/1996). *The Structure of Scientific Revolutions*. 3rd ed. Chicago: University of Chicago Press.

Lavoisier, Antoine Laurent (1789/1965). *Elements of Chemistry*. New York: Dover.

Magie, William Francis, ed. (1969). *A Source Book in Physics*. Cambridge, Mass.: Harvard University Press.

Magnus, P. D. and Craig Callender (2004). “Realist Ennui and the Base Rate Fallacy.” *Philosophy of Science* 71(3): 320-38.

Psillos, Stathis (1999). *Scientific Realism: How Science Tracks Truth*. London: Routledge.

Scheele, Carl Wilhelm (1774/1931). On Manganese or Magnesia; and Its Properties. In *The Collected Papers of Charles Wilhelm Scheele, Translated from the Swedish and German Originals by Leonard Dobbin*, 17-49. London: G. Bell and Sons.

Thomson, Joseph John (1897). “Cathode Rays.” *Philosophical Magazine, Fifth Series* 44: 293-316.

— (1906/1967). “Carriers of Negative Electricity. Nobel Lecture, December 11, 1906.” In *Nobel Lectures: Physics, 1901-1921*, 145-53. Amsterdam: Elsevier Press.

— (1969). “The Electron.” In Magie 1969, 583-97.

Whittaker, Edmund Taylor (1989). *A History of the Theories of Aether and Electricity*.

New York: Dover.