

Natural Kind Essentialism Revisited

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Recent work on Natural Kind Essentialism has taken a deflationary turn. The assumptions about the grounds of essentialist truths concerning natural kinds familiar from the Kripke-Putnam framework are now considered questionable. The source of the problem, however, has not been sufficiently explicated. The paper focuses on the Twin Earth scenario, and it will be demonstrated that the essentialist principle at its core (which I call IDENT) — that necessarily, a sample of a chemical substance, A, is of the same kind as another sample, B, if and only if A and B have the same microstructure — must be re-evaluated. The Twin Earth scenario also assumes the falsity of another essentialist principle (which I call INST): necessarily, there is a 1:1 correlation between (all of) the chemical properties of a chemical substance and the microstructure of that substance. This assumption will be questioned, and it will be argued that, in fact, the best strategy for defending IDENT is to establish INST. The prospects for Natural Kind Essentialism and microstructural essentialism regarding chemical substances will be assessed with reference to recent work in the philosophy of chemistry. Finally, a weakened form of INST will be presented.

1. Introduction

The purpose of this paper is to examine the grounds of supposed essentialist truths concerning natural kinds. The paper contains a negative and a positive part. The negative part consists of sections 2 and 3, which revisit the Twin Earth scenario and demonstrate that the usual reading of the scenario conflates two essentialist principles. The first of these principles is assumed to be false without argument, while the second is accepted on the basis of nothing but an intuition. Prospects for a coherent reading of the scenario are assessed, with the upshot that the traditional literature on the topic fails to support essentialism about natural kinds. The positive part consists of sections 4 to 6, which contain a more scientifically rigorous analysis of the two essentialist principles, focusing on the microessentialist view that essentialist truths concerning natural kinds are truths about their microstructural properties.

Essentialism about natural kinds typically involves claims such as the claim that chemical substances have their molecular structure

essentially, or that elements have their atomic number essentially. These examples are of course familiar from the work of Kripke (1980) and Putnam (1975), but the literature on Natural Kind Essentialism (NKE) has since exploded. It would not be possible in one paper to do justice to this literature and all the different forms of Natural Kind Essentialism that have been defended.¹ Instead, I will focus on a very general and somewhat weak formulation of Natural Kind Essentialism:

(NKE) There are at least some genuine, mind-independent natural kinds that are defined by their essential properties

This broad formulation requires some specification. The core of NKE is that essential properties are responsible for upholding the ‘sameness’ or ‘similarity’ relation between two members of the same natural kind. NKE concerns *general* rather than *individual* essences: the question is about what defines a natural kind rather than the essentiality of kind membership for a given individual.² Most of the literature that concerns purely semantic matters will be neglected in what follows, as the semantics of natural kind terms is not the primary topic. Rather, the focus is on the metaphysical, essentialist assumptions that underlie NKE.³

The importance of NKE is highlighted when it is used to support Natural Kind Realism (NKR), for which I propose the following definition:

(NKR) There are entities—the natural kinds—which reflect *natural* divisions in mind-independent reality

¹ There are numerous internal debates about natural kinds among those who are realists about natural kinds (for further discussion see Bird and Hawley 2011). NKE should be distinguished from *dispositional essentialism*, a thesis about the essentiality of the causal roles of some causal properties, and *scientific essentialism*, the idea that the laws of nature are metaphysically necessary (e.g. Ellis 2001). Many proponents of NKE also defend dispositional/scientific essentialism, but I will remain neutral in this regard.

² I should also mention Dumsday 2010, where an important problem for any account of NKE is discussed. Dumsday labels it the ‘problem of complex essences’. This problem is primarily epistemic: What reasons do we have for thinking that a natural kind essence consisting of a number of essential properties, that is, a ‘complex essence’, is unified into a kind essence? As Dumsday notes, this problem is largely ignored despite its importance. Unfortunately, I will not be able to offer a solution to the problem here.

³ For discussion of the semantics of natural kind terms, see the essays in Beebe and Sabbarton-Leary 2010. Some mention of semantic matters is of course unavoidable as the context of the classic examples from Kripke and Putnam requires this, but the emphasis of the discussion is on metaphysics.

When laid out in this general fashion, NKR can be contrasted with the view that natural kinds reflect *conventional* divisions. However, the interpretation of ‘natural’ is left open here, with the result that NKR encompasses several mutually inconsistent views.⁴ A potentially helpful clarification—even if it has been overused—is that natural kind terms ‘carve reality at its joints’. Accordingly, natural kind terms may be thought to be the set of *concepts* that we use to refer to the mind-independent ‘joints’ of reality. These concepts may carve reality more or less accurately—and sometimes we may be mistaken about whether a concept successfully carves—but the core idea is that some concepts are more ‘natural’ than others. This is by no means a complete analysis of ‘naturalness’, but this is not the place to provide one.⁵

Most familiar examples of natural kinds in accordance with NKE and NKR have faced serious objections. For instance, it has been clear at least since Jaap van Brakel’s (1986) critique concerning the identification of the substance ‘water’ with the compositional formula ‘H₂O’ that the essential properties of chemical kinds are not as easily identified as the early work of Kripke and Putnam may have suggested. More recently, Paul Needham (2011) has argued that the whole project of *microessentialism* or *microstructural essentialism*—the view that chemical substances must be characterized in terms of their microstructure—should be abandoned, as no argument has been provided for the view. Microstructural essentialism, it should be noted, is independent of NKE, but Needham ends up questioning the very notion of a natural kind:

Is any useful purpose served by the term ‘natural kind’ which improves on the use of ‘substance’ and other more clearly delimited general terms from chemistry? (Needham 2011, p. 20)

The question is legitimate, but I think that we must answer in the affirmative. The reason for this, however, is not scientific, but ontological. For without an account of natural kinds in the sense of NKR, it would be difficult to support scientific realism. This, at any rate, is often acknowledged as the primary motivation for thinking that there are genuine natural kinds that support inductive generalizations and

⁴ ‘Mind-independent’ should be understood weakly: divisions in mind-independent reality do not depend on our conceptual schemes (on this, see Tahko 2012).

⁵ See, for instance, Dorr and Hawthorne 2013 for a comprehensive analysis of naturalness. For the purposes of this paper, the preceding broad account is sufficient. For a further distinction between natural properties and natural kinds, see Bird and Hawley 2011.

predictions (Chakravartty 2007, p. 152). But many philosophers (Chakravartty among them) now favour a pluralistic or even a conventionalist approach to kinds. This is no doubt largely because the view that kind essences are intrinsic and microstructural has faced serious criticism. Much of this criticism is accurate and to the point, but it also threatens to undermine scientific realism. One way—although not the only way—to resist this criticism is to defend the combination of NKE and NKR. For a proponent of scientific realism, NKE offers one way to explain why talk of ‘natural kinds’ is viable, if it is viable at all. The worry is that without such an explanation, it is not only the notion of ‘natural kind’ but also ‘(chemical) substance’ that may turn out to be conventional. The starting point of this paper is that even someone like Needham would presumably like to resist this conclusion.

In what follows, the classic case for NKE will be re-evaluated. A more plausible version of microessentialism than the one Needham primarily criticizes (and associates with the work of Kripke and Putnam) will then be presented. Chemical kinds will be the primary example, as they constitute a less controversial example than biological kinds—the work of John Dupré (e.g. 1993) and others has already convinced many philosophers that biological kinds do not have essences, at least not in the traditional sense discussed in the early work of Kripke and Putnam.⁶ One might think that the same would be true of chemical kinds, since recent work in philosophy of chemistry has mounted a strong challenge against traditional chemical essentialism as well.⁷ However, the case is less conclusive, and chemical kinds are still often considered to be paradigm examples of NKE (e.g. Bird 2007, Soames 2011).

One reason for the controversy over chemical kinds is that it is generally not clear what constitutes a ‘chemical kind’—just as it is not clear what constitutes a ‘natural kind’. In chemistry, at least substances, classes of substances, compounds, solutions, and the correlates of other notions that feature in inductive generalizations and predictions made by chemists could be considered to constitute ‘chemical kinds’. In many cases it is quite difficult to judge whether these notions indeed ‘carve at the joints’ in the sense that natural

⁶ There are, however, philosophers who defend (novel) forms of biological essentialism, such as Michael Devitt (2008), Crawford Elder (2008), and Travis Dumsday (2012).

⁷ See, for instance, Weisberg 2005, Hendry 2006a, VandeWall 2007, Needham 2008a, 2008b, 2010, and 2011.

kinds supposedly do. For reasons of simplicity, the focus here will be on substances when it comes to chemical kinds. So, ‘chemical kinds’ should be understood as *chemical substances* in what follows. I leave open whether the applicability of the notion could be extended.

The upshot of this rather limited focus is that even if the argument that follows is successful, there may be very few genuine, mind-independent natural kinds of the sort postulated by NKE and NKR.⁸ What I wish to establish here is that there is hope yet for an account that enables us to maintain scientific realism based on NKE, even in the face of Needham’s challenge and the problems associated with the Kripke-Putnam approach.

Sections 2 and 3 contain an analysis of the ‘traditional’ approach to NKE inspired by the work of Kripke and Putnam. To avoid exegetical issues, I formulate a generic account that captures much of contemporary work in defence of NKE, even if it is not completely faithful to Kripke and Putnam.⁹ For want of a better term, I will call it the *Kripke-Putnam framework*. The Twin Earth scenario serves as my primary example. There are two essentialist principles concerning chemical substances that are relevant for the Twin Earth scenario. I call them INST and IDENT. The first of these (INST) must be false for the Twin Earth scenario to get off the ground, whereas the second (IDENT) is intuitively supported. I will argue that this is a mistake, for if INST is false, it is very difficult to support IDENT. The status of INST and IDENT is a central theme throughout the paper, as I propose that the best case for NKE regarding chemical substances is via a defence of INST.

Sections 4 to 6 go deeper into the scientific background concerning chemical substances. The case of isotopic variation (see LaPorte 2004) will be discussed in section 4 and potential empirical support for IDENT examined. A study of the empirical status of INST will follow in section 5 with special attention to microstructural essentialism. Finally, I will consider a caveat concerning INST and assess how we might go about defining chemical kinds in accordance with NKE. A weakened version of INST is presented in section 6.

⁸ I have independent reasons to prefer a relatively sparse account of natural kinds (see Tahko 2012), so I do not find this particularly troubling.

⁹ See, for instance, Williams 2011 for further discussion concerning exegetical issues (regarding Putnam). Williams argues that Putnam’s essentialism is compatible with non-intrinsic essential properties, contrary to the received view.

The upshot is that although grounding essentialist truths concerning natural kinds is much more difficult than the Kripke-Putnam framework would have it, we can at least establish a methodology for assessing such claims. The case is not conclusive, but it will be suggested that there are reasonable prospects for defending a version of NKE and microstructural essentialism regarding chemical substances.

2. The Kripke-Putnam framework of natural kind essentialism

The established framework of NKE is the *Kripke-Putnam framework*. To be perfectly clear, the framework does not even attempt to be faithful to the motivations or views of Kripke and Putnam, partly because both are notoriously difficult to pin down. What we are interested in is a certain reading of the examples concerning natural kinds familiar from the work of Kripke and Putnam. Proponents of the framework include Alexander Bird (e.g. 2007), Katherine Hawley (e.g. Bird and Hawley 2011), and Scott Soames (2006, 2011). I do not mean to suggest that they are all in the same boat or endorse all aspects of the framework. The Kripke-Putnam framework should be understood as a generalization of the type of approach to Natural Kind Essentialism that the work of Kripke and Putnam has inspired.

One traditional aspect of this framework is that natural kind essences must be intrinsic. The framework is closely associated with an analysis of the necessary a posteriori and the attribution of essential properties to kinds in general, but my emphasis will be slightly different.¹⁰ Let me first reconstruct the Kripke-Putnam framework in terms of the classic case of water and H₂O.

Suppose that ‘water’ designates a *genuine*, mind-independent natural kind. A genuine natural kind must have a determinable set of identity and existence conditions, and we should generally be able to state them. Whether water in fact is a genuine kind (or whether there are *any* such kinds) is open to debate; we will return to this debate later. According to the Kripke-Putnam framework, we know that samples of water are made up of H₂O molecules.¹¹ If it is also the case that water has its actual microstructure essentially—even though

¹⁰ I have discussed the necessary a posteriori in detail in Tahko 2009.

¹¹ Caveats regarding ‘H₂O’ have been pointed out by several philosophers of chemistry (e.g. van Brakel 2005, Weisberg 2005). It is not always clear whether we are dealing with a single Mind, Vol. 124 . 495 . July 2015

empirical work is needed to determine what individual samples of water are made up of—then ‘Water is H₂O’ is a metaphysically necessary a posteriori essentialist truth.

This is how the Kripke-Putnam story goes, but it is clear from the point of view of philosophy of chemistry that we are not, in fact, presently able to give a complete description of the microstructure of water, even if we may be able to do so in some other cases:

Prospects for a purely microscopic description vary, then, from one group of substances to another. The relative ease with which this can be done for the molecular substances of organic chemistry is not a guide to substances in general. This is not to deny, of course, that even in the more recalcitrant cases, there is a microstructure. ... What doesn't follow from this is that the details of the microstructure of any particular substance are reasonably well known, and certainly not that they are independent of macroscopic constraints or somehow determine the macroscopic features of substances or that substances are in some clear sense ‘nothing but’ their microconstituents. (Needham 2011, p. 17)

That water does have its actual microstructure essentially is usually considered to be knowable a priori, but we will see that this assumption must be clarified. The core of the Kripke-Putnam framework of NKE as it is usually understood is that the combination of an essentialist a priori truth about a given natural kind essence and empirical information about the microstructure of that natural kind are needed to establish metaphysically necessary theoretical identity sentences that we are all too familiar with.

The account faces an initial concern familiar from Putnam's (1975) Twin Earth scenario: Could the chemical properties of water be reproduced by some molecular structure other than H₂O—say, XYZ? If so, should we consider this substance to be water? The usual answer to the second part of the question is widely accepted: XYZ is not water. The empirical details are rarely discussed, at least by metaphysicians. This is no doubt partly because most metaphysicians lack the necessary knowledge of chemistry to be able to say much about it (see Soames 2005, p. 191), but generally at least the *metaphysical* possibility of XYZ reproducing the chemical properties of water is simply assumed.

molecule, a group of molecules, the molecular structure ‘in the abstract’, or something else. On this, and the molecular paradigm in general, see also Needham 2008a, p. 928.

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Before we can assess this challenge, it should be made clear what is meant by ‘chemical property’. Putnam was originally mostly interested in the *macroscopic*, phenomenological properties of water such as boiling point or solubility, as they are properties that Twin Earth water shares with Earth water. Whether these macroscopic properties reduce to *microscopic* properties such as electron configuration is a matter of debate (see especially Needham 2011), but this is typically assumed in the Kripke-Putnam framework. In any case, Putnam (1990, p. 69) states quite explicitly that he thinks (and thought already in 1975) that microstructure determines the macroscopic properties—the ‘lawful behaviour’—of chemical substances such as water. This ‘lawful behaviour’ is manifested by chemical properties, that is, properties of a chemical substance that typically become evident in chemical reactions, such as oxidation. Using philosophical terminology, we might define a *chemical property* as follows:

Chemical property =_{df} A property of a chemical substance *in virtue* of which the substance can undergo chemical reactions

To understand what is meant by ‘in virtue of’ in this connection, consider electronegativity—the ability of an atom or a functional group of a molecule to attract electrons. For the purposes of interpreting the Twin Earth scenario, tracking the *source* of this ability is important. In the case of electronegativity, the ability of an atom to attract electrons is influenced by its nuclear charge. Atoms with a higher electronegativity attract valence electrons more strongly, hence the distance from the atom’s nucleus to the electrons is shorter. There is a straightforward way in which electronegativity is related to the microstructural properties of the substance, to its nuclear charge in particular. However, Putnam’s original examples concern chemical properties that are primarily macroscopic, such as boiling point and solubility. We do of course have a good idea about the (microstructural) source of chemical properties such as these, but the story is not entirely uncontroversial, especially when it comes to the distinction between physical and chemical properties. For instance, in the nineteenth century it was still common to consider properties such as boiling point to be physical properties, not necessarily connected with the chemical properties of a substance (Needham 2008b, pp. 66–7). In any case, what we need to keep in mind here is that Putnam’s assumption that microstructure determines the chemical properties of a substance quite generally is absolutely central for the Twin Earth scenario.

Having clarified what is meant by chemical properties in this context, we can see that it is an empirical question whether it is *physically* or *chemically* possible that all the chemical properties of water could be reproduced by XYZ—some alternative microstructure.¹² The role of empirical knowledge regarding the existence of *metaphysically* possible microstructures that could replicate the chemical properties of water is debatable. Chemistry will presumably be of some help here, but it is often thought that we also need metaphysical a priori work to determine what is metaphysically possible. In later work Putnam himself expressed serious doubts about extending the Twin Earth scenario across metaphysically possible worlds and even said that the question about the possible variation of the laws of physics with regard to water ‘makes no sense’ (Putnam 1990, p. 70). Regardless of this, a great number of metaphysicians continue to discuss the Twin Earth scenario in a manner where this question appears to be central. Moreover, Putnam reads Kripke to be concerned with *metaphysical* possibility.

Let me take a moment to discuss the distinction between physical and metaphysical modality. A great deal, if not all, of what will be said below could in fact be understood as dealing with *physical* modality. Most examples will involve empirical considerations, which are not obviously relevant for metaphysical modality. Accordingly, I think that what follows will be of interest even if the reader is sceptical about the notion of metaphysical modality to begin with.¹³ However, much of the literature on NKE deals with metaphysical modality, so some mention of its relevance should be made. In its most simple form, the relevance of metaphysical modality for the topic at hand concerns alternative laws of physics, for example, could alternative laws of physics enable the possibility of XYZ reproducing the chemical properties of (actual) water? This is the question that ‘makes no sense’ to Putnam, but it seems to me that the question itself is perfectly comprehensible. Indeed, even scientists sometimes talk about scenarios in which the laws of physics are slightly different from the actual laws.

¹² Physical possibility is understood as being restricted by the laws of physics of the actual world. For what it is worth, the answer to this empirical question is usually assumed to be ‘no’, and this is most likely correct. It is another question whether alternative laws of physics are metaphysically possible—we will return to this below.

¹³ For a recent attempt to clarify the notion see Nolan 2011, whose conclusion is rather deflationary. I take the notion of metaphysical modality ‘seriously’, by which I mean that I believe there to be a legitimate use for it. Nolan and indeed later Putnam do not seem to be so optimistic, but this is not the place to settle the debate.

Another matter is how we are supposed to *know* the answer to questions concerning alternative laws. Unless we have a story about how to restrict the space of merely possible laws, this discussion does not make very much sense. But there is one clarification that should be made. Since we *do* entertain scenarios with alternative laws of physics, there must be something beyond the laws of logic that guides our discussion about these matters. What I mean is that scenarios with alternative laws do not generally concern just *any* laws, but rather laws that are restricted by some broader considerations. Sometimes such restrictions are called *metaphysical laws*, which may perhaps be thought as the most ‘privileged’ laws of nature.¹⁴ Now, I will not speculate about which laws might have such a privileged status, I only wish to note that the issue regarding alternative laws and our epistemic access to them is certainly more complicated than Putnam’s reaction suggests. Since it will not be possible to settle the matter here, I propose that readers sceptical about metaphysical modality should simply consider the arguments that follow from the empirical point of view, that is, in terms of physical rather than metaphysical modality.

We should not lose sight of the main purpose of this section, which is to examine the origins of the supposed essentialist content that underlies the Twin Earth scenario. The key here is connecting the microstructure and the chemical properties of a substance. To this end, we can distinguish two essentialist principles. The two candidate principles are the following:¹⁵

- (INST) Necessarily, there is a 1:1 correlation between (all of) the chemical properties of a chemical substance and the microstructure of that substance
- (IDENT) Necessarily, a sample of chemical substance A is of the same chemical substance as B if and only if A and B have the same microstructural composition¹⁶

¹⁴ See Nolan 2011, p. 329, who attributes the idea to Jonathan Schaffer.

¹⁵ ‘Microstructure’ in these principles should be understood as a placeholder for whatever level of microstructural accuracy one wishes to focus on. In the traditional literature, questions of quantum chemistry, for instance, are not typical, but Putnam’s occasional use of ‘deep structure’ in place of ‘molecular composition’ makes it clear that the level of microstructural accuracy is supposed to remain open.

¹⁶ ‘Chemical substance’ will generally be a chemical compound, although I acknowledge the difficulties in defining (pure) chemical compounds. In any case, INST and IDENT do not
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Both of these principles, if true, are typically considered to be knowable a priori — or so the literature would suggest.¹⁷ On the face of it, the Twin Earth scenario seems to focus on IDENT rather than INST, since what is at stake are our intuitions in cases where we *do* encounter substances such as XYZ, which replicate the chemical properties of water. So, it seems that if the scenario is possible, then INST must be false, for both H₂O and XYZ are associated with (all of) the same chemical properties — a many:1 relationship. There are, however, at least two ways to interpret the scenario, reflecting different views about the modality involved (physical or metaphysical).

Firstly, the scenario could be interpreted as metaphysically possible in the sense that alternative, metaphysically possible laws of physics would enable XYZ to replicate the chemical properties of water. Secondly, we could be dealing strictly with physical possibility, that is, the scenario only concerns a remote location in our universe. As we saw, Putnam (1990, pp. 61 ff.) has expressed concerns about the first, ‘metaphysical’ reading of the scenario, and he explicitly states that what he meant was a remote location in our universe and hence physical possibility (even though he used the term ‘logical possibility’; see also Shoemaker 1998, p. 69). But if the scenario concerns physical possibility, then the empirical question of whether another chemical substance could produce the chemical properties of water becomes central, and — to anticipate the discussion below — this is quite unlikely. The scenario can certainly be discussed even in this eventuality, but if it is in fact physically *impossible* for XYZ to replicate the chemical properties of water, and metaphysical possibility is already ruled out, then we must instead be talking about mere *epistemic* possibility. Indeed, this seems to be what Putnam had in mind.

So, as far as Putnam is concerned, IDENT can only concern physical modality, and in the Twin Earth scenario we entertain the epistemic possibility that the microstructure of water is XYZ. But once we *know* what the microstructure of water is, we know that it is physically necessary:

Since there is a standard description of microstructure, and microstructure is what determines physical behavior (laws of behavior), it seemed to me

concern mixtures. As we will see, they can be applied to elements, although most of the examples discussed concern compounds rather than elements.

¹⁷ This is of course controversial. See Tahko 2013 for a previous formulation of these principles in epistemic terms, and for further discussion about their epistemic status.

that the only natural choice for a criterion of substance-identity was the microstructural criterion. (Putnam 1990, p. 69)

The caveat, which Putnam does *not* acknowledge, is that even if a correlation between microstructure and chemical properties does exist, it might not always be possible to specify the microstructure without relying on macroscopic features. Indeed, there is no general formula according to which microstructure determines macroscopic features. But since this is what much of the literature on NKE assumes, we should at least examine the prospects of establishing a sufficiently complete description of how microstructure could determine macroscopic features.

3. Re-evaluating the Metaphysical Reading of the Twin Earth Scenario

For the time being, I wish to set aside Putnam's sceptical remarks and consider the *metaphysical* reading of the scenario. Many contemporary philosophers who write about natural kind essences write *as if* essentialist principles such as INST could be extended across metaphysically possible worlds. For instance, Bird and Hawley (2011, p. 220), who think of natural kinds in terms of complex universals, frequently resort to talk of possible worlds, transworld identity, and 'local laws' at a given world. Similarly, Soames (2005, p. 191), when discussing the Twin Earth scenario, considers whether there could be metaphysically possible microstructures that could reproduce the chemical properties of H₂O. I should again stress that I have not forgotten those sceptical about metaphysical modality. But because the metaphysical reading of the Twin Earth scenario is very popular, we should at least assess it.

In the metaphysical reading of the Twin Earth scenario, the falsity of INST must be assumed at the outset. If INST — understood as concerning metaphysical necessity — were true, then there would be no metaphysically possible world where XYZ reproduces the chemical properties of water. Accordingly, if there is a coherent, metaphysically serious reading of the Twin Earth scenario, it must rely on IDENT. IDENT guides our intuitions to the conclusion that Twin Earth water (XYZ) is not water. For the thought experiment to get off the ground at all, it must be assumed that XYZ could produce the same chemical properties as H₂O — and the question is whether this substance would be water. Our reply is supposed to be that XYZ would *not* be water,

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leading us to conclude that water does, after all, have its actual microstructure by metaphysical necessity.

This strategy, from IDENT to the metaphysical necessity of microstructure, is *not viable*. If two distinct microstructures could produce the same chemical properties (in the actual world or in another metaphysically possible world), then what reason would we have to think that IDENT is true? Short of an *intuition*, no such reasons are provided in the literature. In fact, there are many who do not share this intuition, most notably philosophers of chemistry, but also metaphysicians (van Brakel 1986, Needham 2011, Lowe 2011, Weisberg 2005). Here is van Brakel's conclusion regarding the role of molecular structure in chemical substances:

Because it turns out that no clear meaning, if any, can be given to the notion of molecular structure, it is not possible to specify what the reference and essence of water is in terms of its molecular structure. (Van Brakel 1986, p. 303)

This does not mean that *no* microstructural essentialist account of water is possible, but it certainly demonstrates that the status of IDENT is debatable. Of course, if van Brakel is correct, there is little hope for using the notion of 'molecular structure' in essentialist principles like INST and IDENT in the first place. Partly because of this, I have been discussing 'microstructure' rather than 'molecular structure' despite the vagueness that this introduces. There is also a suspicious look of reductionism in these principles, namely, if microstructure determines chemical properties, then it seems that chemical properties should be reducible to microstructure. But this is a problematic assumption, one that requires an argument. In sections 4 to 6 we will assess the prospects for an essentialist story that could address these concerns.

We are now in the position to summarize the role of INST and IDENT. Traditionally, the Twin Earth scenario (or the underlying intuition) is considered to constitute a strong case in favour of the essentiality of microstructure for chemical substances. But it turns out that the starting point of the scenario is questionable, since the metaphysical reading of the scenario must assume the falsity of INST and rely on our intuitions in defence of IDENT. A re-evaluation of both principles is in order.

If the Twin Earth scenario assumes that INST is false, why should a proponent of NKE be interested in it? One reason is that INST would constitute a better case to the effect that the chemical properties of a

chemical kind are essential for that kind. This would suggest a form of microstructural essentialism concerning chemical kinds, but I should note that NKE can also be formulated in a manner which is neutral regarding microstructural essentialism. The line of thought that this paper develops is the following:

- (1) According to the metaphysical reading of the Twin Earth scenario, IDENT supports the conclusion that chemical substances have their microstructure by metaphysical necessity.
- (2) IDENT is generally supported with nothing more than an *intuition*, but experts on the topic, philosophers of chemistry in particular, do not share this intuition.
- (3) INST, however, corroborates IDENT. So, if we could establish INST, we would have a better case for IDENT.

The speculative conclusion building on (1)–(3) that will be assessed is:

- (4) There are reasonable empirical grounds for INST. The metaphysical reading of INST *may* also be supported. The combination of INST and IDENT would suffice to establish NKE (in its microstructural essentialist form) concerning chemical kinds.

So far, I have elaborated on (1) and (2).¹⁸ What about (3)? There is an apparent connection between INST and IDENT. If there is a 1:1 correlation of microstructure and chemical properties, as INST states, then chemical substances A and B are samples of the same chemical substance if and only if they have the same microstructure. Two samples are plausibly not of the same substance unless they have the same chemical properties. To illustrate this, consider the converse. What if we had two samples that differ in terms of chemical properties *and* microstructure? What could these samples have in common that would lead us to conclude that they are of the same chemical substance, hence of the same chemical kind? Certainly, the intuitive case is much stronger here than it is with IDENT, for the ‘intuitive’ case in support of IDENT only requires sameness of *one* of these features, namely microstructure. The question is whether sameness of chemical properties by itself is enough for sameness of kind membership. But it is never suggested that sameness of chemical properties and sameness

¹⁸ More discussion regarding (2) as well as (4) will follow in Sects 4 to 6.

of microstructure *together* would not be enough to establish sameness of kind membership. The reason, I take it, is that there are no other candidate features that *could* establish sameness of kind membership. Since INST states that microstructure and chemical properties are always aligned, it seems that there is a necessary connection between INST and IDENT.

Some might have doubts about this conclusion, for there are cases where two samples with distinct microstructures have some or even most of their chemical properties in common. One might go on to suggest that sometimes the similarity of *most* chemical properties is sufficient for fixing kind membership to the same chemical substance, so that we have a many:1 relationship between microstructure and chemical substance despite the possibility of slight variation in chemical properties. This might seem to count as evidence against (3), as something close to INST could, perhaps, be maintained, but IDENT could certainly not. What could such cases be? Minerals are a possible candidate: the common mineral *olivine*, for instance, occurs in two varieties, a magnesium-rich and an iron-rich variety; this is reflected in its chemical formula, $(\text{Mg}, \text{Fe})_2\text{SiO}_4$. The chemical properties of olivine vary according to whether it is Mg-rich or Fe-rich. For example, only the latter can exist stably with silica minerals such as quartz. Is olivine an example of a chemical kind that can have different microstructures? I do not think so. Minerals such as olivine (also feldspars and pyroxenes) are typically considered as *mixtures* rather than compounds; they are best understood as *solid solutions*.¹⁹ Hence, there are independent reasons to think that olivine and similar minerals do not constitute kinds at all; they are mixtures of two elements in close proximity on the periodic table that remain in a homogeneous state.

Note that the well-known case of jadeite and nephrite can be dismissed on similar grounds. The two minerals share many of their chemical properties, yet differ in terms of microstructure. However, jadeite and nephrite are not *exactly* identical in terms of chemical properties, and a chemist would never make the mistake of calling them by the same (chemical) name once this is known.²⁰ For instance,

¹⁹ See, for instance, Nesse 2011 for an introduction to mineralogy and solid solutions. INST and IDENT do not apply to olivine and its ilk at all, in so far as they are considered solid solutions rather than chemical compounds.

²⁰ See LaPorte 2004 for an extensive discussion of the jadeite/nephrite case, and Bird 2010 for some critical remarks.

jadeite is somewhat harder and less prone to scratches due to its dense crystal structure and higher specific gravity — it is in fact a pyroxene mineral. There may be other potentially problematic cases which will have to be assessed on a case-by-case basis, but so far we have seen no reason to doubt the connection between INST and IDENT, as suggested in (3).²¹

What remains to be discussed is whether a case can be made for the truth of INST. I believe that some progress can be made, at least in the *methodological* sense that we can get a better idea about what sort of combination of empirical and metaphysical arguments would be needed to establish INST. At this point, it might also be wondered whether there is empirical support for IDENT. If this were the case, then perhaps we could avoid the difficulties surrounding INST (which could be used to support IDENT).

4. The empirical status of IDENT

It appears that the intuitive case in favour of IDENT is inconclusive. But is IDENT supported by actual science? Does microstructure determine which chemical substance a sample belongs to — like IDENT suggests — in the practice of chemists? In the case of compounds, the requirement of having the same proportions of the same elements, as the *law of definite proportions* states, is an important constraint. An obvious complication for this requirement is introduced by isotopic variation. Is pure ‘heavy water’ (as D₂O — deuterium oxide — is commonly known) also water?

LaPorte (2004, pp. 104 ff.) discusses this very example and constructs a Twin Earth scenario from it as follows. Before the discovery of isotopic variations, some scientists travel to ‘Deuterium Earth’ where all water is pure D₂O.²² The scientists discover that despite its apparent similarity with Earth water, Deuterium Earth water behaves quite differently (e.g. it kills fish), and eventually decide to call this new liquid ‘dwater’. After some time has passed, the scientists return to Earth, taking a sample of ‘dwater’ with them. In the meanwhile, isotopic variations have been discovered on Earth. When Earth scientists examine the sample of ‘dwater’ they discover that they are not in

²¹ Some other potential counterexamples will be discussed in Sect. 4.

²² ‘Heavy water’ is sometimes also used to refer to water with an atypically high deuterium-to-hydrogen ratio, i.e. a mixture, but it seems that LaPorte has in mind a case where all water is pure deuterium oxide.

fact dealing with a new liquid at all, but just with an uncommon variety of water. LaPorte concludes that Earth scientists did not discover that water is H_2O , nor did the scientists who travelled to Deuterium Earth discover that ‘dwater’ is D_2O . Rather, at least on the face of it, the scenario seems to support a more deflationary conclusion: how we label chemical substances is a matter of convention, as is the extension of natural kind terms.²³

The significance of LaPorte’s Twin Earth scenario for the current discussion is two-fold. Firstly, it highlights the questionable status of IDENT, as both the intuitive and supposed empirical support for the principle are under scrutiny. Secondly, the scenario reminds us of the conventionalist challenge to NKE.²⁴

There is certainly an appearance of conventionalism here, and that appearance may be supported by history. The International Union of Pure and Applied Chemistry (IUPAC) decided to count isotopic variants as the same substance already in their 1923 ruling, but this was hardly an uncontroversial decision (Hendry 2006a, p. 867). In fact, some still think that H_2O and D_2O should be considered different substances (Needham 2008b; 2011, p. 11), and the debate is on-going (Hendry 2010, pp. 926–7). The problem, summarized appropriately by Weisberg (2005), is that we ought to be able to reconcile our ordinary language natural kind term ‘water’, and the notion of a ‘pure’ chemical substance which takes into account isotopic variation.²⁵ My initial reaction to this problem is the same as Weisberg’s. Rather than dealing with just one kind, we are more plausibly dealing with a higher-order term—a genus—and a number of lower-order instances—species—reflected by the different isomers (i.e. distinct substances with the same compositional formula) of H_2O . However, Weisberg is quick to point out that the genus/species solution as well runs into trouble,

²³ For further discussion of the case of H_2O and D_2O and similar cases, see Bird 2010; Needham 2008b; Oderberg 2007, pp. 162–6; Salmon 2005, pp. 258–9.

²⁴ In addition to LaPorte’s, recent accounts with a conventionalist flavour include Dupré 1993, Daly 1996, Sidelle 2009, and Varzi 2011; see also Needham 2011 (who, it should be noted, does *not* favour a conventional reading of ‘chemical substance’). A potential way to save at least the spirit of NKE would be to follow Dupré and adopt a type of ‘promiscuous realism’ regarding kinds: if the differences between H_2O and D_2O can be described in terms of their *physical* rather than chemical properties, perhaps we could say that, for physical purposes, they are two distinct substances, but still maintain that for chemical purposes they can be classified as the same substance. Dupré’s arguments for promiscuous realism concerning *biological* kinds are convincing, but I am reluctant to accept them in the case of chemical kinds, for reasons which will become evident when I discuss Hendry’s reaction to LaPorte’s scenario.

²⁵ For further discussion on ‘purity’, see Needham 2010.

at least in the case of water. This is primarily due to the relative abundance of heavy water. There are good reasons to consider heavy water to be a substance in its own right rather than a lower-order instance of H_2O , given its different chemical properties as well as practical applications (e.g. being lethal to some organisms, having a different freezing point, and having an important use in nuclear reactors). Hence, the solution is still not satisfactory — it also disfavours the claim that there is empirical support for IDENT.

There are perhaps even more problematic cases than the case of isotopic variation. For instance, there are cases where different samples of what appear to be the same substance vary in terms of the ratios of the elements that are present, thus violating the law of definite proportions.²⁶ It suffices to say that the empirical case for IDENT is starting to look highly questionable, even if it is not conclusively ruled out. Let us see if INST fares any better.

5. The empirical status of INST

INST states that there is a necessary connection between the microstructure of a chemical substance and the chemical properties of that substance. In the spirit of the traditional reading of the Kripke-Putnam framework, this suggests that the microstructure of chemical kinds is central to identifying them. But already van Brakel's early reaction to the Kripke-Putnam framework made it clear that it is incorrect to view a body of water as a collection of water molecules. Van Brakel's reaction is the established view in philosophy of chemistry (Needham 2008a, p. 928; 2011, pp. 8–15). However, there is no absolute consensus about these matters even amongst philosophers of chemistry. For instance, Hendry (2006a, p. 871) concurs that identifying water with H_2O fails to capture the molecular complexity of water, but points out that if isolated water molecules were to come into contact and react, the result would be the microstructure of water. Yet this does not entail that the essences of water and other supposed chemical kinds are *reducible* to their microstructure.²⁷

²⁶ These are known as *non-stoichiometric compounds*, or *Berthollides*. One example is palladium hydride. See Needham 2007, 2008a, and Hendry 2010 for some discussion of Berthollides. The issue is also mentioned in van Brakel 1986.

²⁷ This is known by philosophers of chemistry, but often ignored in metaphysics (cf. Barnett 2000).

Some metaphysicians are already adapting to this. Lowe (2011), for instance, is sceptical about microstructural essentialism, at least in the case of water, although he does not go into much detail about the chemistry. Lowe is of the opinion that any necessary features that water might have will be macroscopic, reflecting Needham's line (2011, p. 18).²⁸

Is there any way to uphold INST—or microstructural essentialism—given these problems? Perhaps there is. Drawing on Lavoisier, Hendry (2006a, pp. 868–9) suggests that the defining characteristic of elements is nuclear charge (rather than atomic weight), since nuclear charge is largely responsible for the chemical properties of elements. Based on this suggestion, hydrogen and deuterium, since they have the same nuclear charge, would be instances of the same element—this is compatible with IUPAC's ruling concerning isotopes. Of course, this does not mean that the chemical properties of two isotopes are *identical*, but they are nevertheless typically closely (and systematically) related.

Can this criterion be extended to compounds as well? Hendry seems to think so. The idea, as I see it, is that the criteria for defining elements carry over to the case of compounds due to the fact that compounds consist of elements. Hendry suggests that the role of nuclear charge is equally important in giving elements and compounds the chemical properties that they have. If this is correct, then it appears that LaPorte's Deuterium Earth scenario—quite like Putnam's original scenario—neglects some modal constraints which govern the behaviour of elements (and compounds). However, this does not mean that all of the chemical properties of elements carry over to compounds. Regarding LaPorte's scenario, we observed that H₂O and D₂O differ in some important respects. Yet they also share many core features, such as having melting and boiling points within a few degrees Celsius from each other.

Here we are at the heart of the problem regarding microstructural essentialism. As Needham convincingly argues, 'anyone wanting to give a microdescription of water who simply offers "H₂O" fails miserably' (Needham 2011, p. 9). What the microstructural essentialist should offer is a defence of a plausible essentialist principle, such as INST. If correct, INST enables us to construct an argument for the

²⁸ An important point to which Lowe draws attention is that in the original Twin Earth scenario, the reducibility of the essences of chemical substances to their microstructural properties seems to be assumed. Compare this to IDENT, which suggests that a chemical substance with the molecular structure H₂O is water *regardless* of its chemical properties.

necessity of a microstructural criterion in defining chemical kinds. INST suggests that the chemical properties responsible for the stereotypical, macroscopic behaviour of chemical substances are necessitated by the microstructure of that chemical substance and could not be reproduced by any other microstructure. Now, this does not mean that a macroscopic description of water is *impossible*, rather, it means that there is a 1:1 correlation between the microscopic and the macroscopic properties of a chemical substance. Typically, the microessentialist also holds that the macroscopic properties of a chemical substance are *determined by* its microscopic properties, but there may be no general recipe for how this is supposed to happen, so further arguments are needed to establish full-blown microstructural essentialism of this type.

Moreover, situations where a certain microstructure is realized without the (normal) corresponding macroscopic properties might be possible. An analogous situation may be a case where a certain value of the average kinetic energy of the constituent molecules of a gas does not necessarily imply that the gas has the corresponding temperature.²⁹ This would suggest that even if there were a 1:1 correlation between microstructure and chemical properties, it might not always be possible to *specify* the microstructure without relying on macroscopic properties. So, it may not always be possible to give an accurate microstructural characterization that does not already assume certain macroscopic properties. These limitations may be, at least in part, merely epistemic, but they do complicate the situation somewhat.

Consider the case of isotopic variation again. The chemical properties of different isotopes do not align *exactly*. However, we could perhaps determine a set of core chemical properties common to the different isotopes, where slight variation from these core chemical properties could be accommodated (compare with Weisberg's genus–species hierarchy). Because different isotopes share the same nuclear charge and electron configuration, their chemical properties are very similar. The most notable differences are due to the variation in atomic weight, illustrated by the kinetic isotope effect: the extra neutron in deuterium, for instance, causes it to react more slowly than ¹H (common hydrogen). The case of hydrogen is the most radical because of the great relative difference in the masses of ²H and ¹H, but with heavier elements the effect is much smaller (and it can be

²⁹ Thanks to an anonymous referee for *Mind* for suggesting this case.

systematically determined). Accordingly, there is at least an initial plausibility to Hendry's suggestion. In contrast, a difference in the number of protons in two sample substances would count towards them being samples of two distinct substances if elements are defined in terms of nuclear charge. So, here we have one empirical criterion that appears to support INST, since a difference in microstructure (due to a difference in the number of protons) would also necessitate a significant difference in the chemical properties of the sample substances.³⁰

The upshot is that we should assess chemical compounds' status as chemical kinds on a *case-by-case* basis. At least in some cases this is also empirically viable. Water is in fact a notoriously difficult case, but the status of other compounds—and especially elements—appears somewhat easier to determine.

6. The metaphysical status of INST

We have seen that traditional microstructural essentialism familiar from the Kripke-Putnam framework as well as the essentialist principle IDENT, according to which microstructure fixes the identities of chemical substances, are lacking both in terms of metaphysical and empirical support. However, INST, which states that there is a 1:1 correlation with a microstructure and a set of chemical properties, has at least some empirical support. It remains to be settled whether INST, as has been argued, corroborates IDENT. Moreover, is the stronger reading of INST as a *metaphysically* necessary essentialist principle viable? I will not attempt to establish this stronger reading of INST. Rather, I will make some methodological suggestions that should be taken into account in any attempt to establish the stronger reading, hoping to demonstrate that it is at least coherent and compatible with chemical practice.

Even if INST is correct and there is 1:1 correlation between microstructure and a set of chemical properties, it is left open how microstructure is supposed to determine chemical properties—as full-blown microessentialism would seem to require. There appears to be no easy, general answer available. Because of this, the original,

³⁰ I am bracketing several issues concerning vagueness about the 'sameness' of microstructure, as well as the undeniable sense in which water may (also) be understood as a macroscopic substance. A degree of vagueness is unavoidable, but the case of isomers may be solved by understanding 'sameness' of microstructure in a more fine-grained sense, taking into account possible stereoisomers, structural isomers, etc.

highly general formulation of INST may be unwarranted. As an illustration, consider acids and bases: their definition has gone through a variety of changes involving both micro- and macroscopic characteristics (Stanford and Kitcher 2000, pp. 115 ff.). If particular acids and bases must be defined in terms of macroscopic characteristics, then they do not constitute chemical substances according to INST. Yet, since particular acids and bases are typically *considered to be* chemical substances, INST cannot apply to all chemical substances. Accordingly, in order to retain the normal use of ‘chemical substance’ in chemistry while also preserving the full-blown microstructural essentialist principle that chemical kinds are to be defined in terms of microstructure, we must revise INST. I suggest that we qualify INST as follows:

(INST*) Necessarily, there is a 1:1 correlation between (all of) the chemical properties of a chemical substance *that constitutes a chemical kind* and the microstructure of that substance

On the face of it, INST* may seem to give rise to circularity. If we are defining chemical kinds with the help of an essentialist principle, then surely the principle should not contain mention of chemical kinds. However, INST* should not be understood as an explicit definition of chemical kinds.³¹ INST*, together with other principles, may provide an implicit definition, but it does not give rise to vicious circularity. The purpose of the qualification is to allow for the possibility that some chemical substances, as discussed by chemists, are not even in principle definable in terms of microstructure, contrary to INST. This move will likely seem undesirable from the point of view of chemistry, given that the notion of ‘chemical kind’ appears to become artificial. But the claim being researched here is that if there is *any* validity in the microstructural essentialist’s approach, then it must be based on the special status of those chemical substances that do conform to INST—this idea is captured by INST*. So, the view suggests that there is a special class of chemical substances—genuine chemical kinds—reflecting INST*, while acknowledging that chemical practice recognizes chemical substances that do not allow for a microstructural analysis.

Following this line of thought, the microstructural essentialist can accommodate the idea that particular acids and bases constitute

³¹ Thanks to Severi Hämäri and Markus Pantsar for discussion regarding this point.

chemical substances by distinguishing an ordinary, ontologically imprecise usage of ‘chemical substance’ from an ontologically precise usage. The suggestion is that the ontologically precise, microstructurally definable chemical substances could be understood as ‘chemical kinds’. There is a good reason for this terminological suggestion: as we saw in the beginning, Needham (2011, p. 20) asks whether any useful purpose is served by the term ‘natural kind’ which improves on ‘substance’. Well, if the microstructural criterion can be made to work, then it would be helpful to distinguish it from the ordinary usage of ‘chemical substance’, since there are cases which the microstructural criterion rules out. Hence, some work is indeed done by the notion of a ‘chemical kind’ which improves on ‘chemical substance’, namely, it distinguishes an ontologically privileged subset of chemical substances.

However, we do not yet have a complete sense of how microstructure determines chemical properties or how the latter reduce to the former, if that is indeed the case. Accordingly, INST* only states a relatively weak, but empirically defensible criterion for chemical kinds. If this is correct, the case for a stronger reading of INST* remains to be established. This would entail a jump from physical to metaphysical modality. I will not attempt to fully justify such a jump here, but in what follows a line of thought will be examined that might be of some help for those who would like to pursue the stronger reading.

The case concerning elements presented in the previous section provides a good starting point. If we buy into Hendry’s project, then nuclear charge is the most promising *possible* candidate for the defining characteristic of elements. The historical background, especially Lavoisier’s work, is illuminating in this case. According to Hendry, Lavoisier intended element names to be indifferent to the combinations in which they occur in such a way that the presence of an element in a compound explains its chemical properties. It turns out that nuclear charge rather than atomic weight is the best candidate for a property that satisfies this criterion, as we have already seen (Hendry 2006a, pp. 868–9; 2012, p. 267).³²

In this picture, the source of the essentialist claim that nuclear charge is the defining characteristic of elements does not appear to be the *empirical* analysis of elements and compounds, as Lavoisier’s empirical methods were wanting in any case. Rather, the modern

³² For more details on the historical case, see Hendry 2005, 2006b, 2012, but note Scerri’s (2006) differing reading.

empirical analysis corroborates the idea that something about elements is preserved when they form compounds. If this is correct, then we are entitled to ask: *Why* should we make such an assumption?

Here we would do well to recall F. A. Paneth's (1962/2003) classic discussion of the epistemological status of elements. Paneth argues that despite Lavoisier's revolutionary, empirical method, the 'meta-physical nature' of the concept of element already assumed by the Aristotelians survives in Lavoisier's work:

The essential point, after all, is the assumption, which is retained, that the simple substance is present in some latent form (i.e., in such form that the properties which it has in the pure state are not recognisable) in the composite ones, and that it explains their behaviour. (Paneth 1962/2003, p. 126)

Paneth concludes that Lavoisier, even though he did not engage in an a priori delimitation of the number of 'chemical basic substances', unlike the alchemists and Aristotelians before him, was equally committed to the theoretical requirement that 'basic substances', or 'elements' could be prepared as non-decomposable 'simple substances', or 'free elements'.³³ A crucial part of this theoretical requirement is that if we encounter chemical properties that cannot be explained with reference to the known elements, we can postulate the elements from which their chemical properties must be derived, *regardless* of whether or not these elements have been, or even *can* be prepared as *free* elements. As Paneth (1962/2003, pp. 127–8) points out, fluorine and radium were accepted as elements well before the empirical work of Moissan and Curie, who were able to prepare them as free elements. This was exactly because compounds manifesting chemical properties hitherto unknown — such as the properties of hydrofluoric acid and the radioactive salts of radium — needed explaining. The existence of elements responsible for these properties was *inferred* indirectly, not discovered by direct empirical research. What Paneth calls the 'meta-physical' idea of the concept of element is hence strikingly close to an essentialist principle similar to INST. The chemical properties of compounds are a result of the interaction of the elements present in those compounds, which would explain the 1:1 correlation of microstructure and chemical properties. The causal process by which we arrive at the chemical properties of compounds starting with the interaction of free

³³ As Hendry (2006b, p. 342) notes, there is a risk of confusion in Paneth's use of 'basic substance' and 'simple substance'. Because of this, I adopt Hendry's more accurate 'element' and 'free element', respectively. See also Hendry 2012, pp. 262 ff.

elements—and what survives in this process—is what interests us. This is what Paneth considers to be a mark of the ‘metaphysical nature’ of the concept of element, which Hendry calls the ‘core conception’. The case is hardly conclusive, but it makes a start towards a metaphysically robust analysis of microstructural essentialism, since the principle that underlies these indirect inferences must be something like INST.

What I think we should take from this discussion is that defending essentialist principles like INST (or INST^{*}) in the stronger, metaphysical form, requires an account of the candidate essences that would explain the causal processes that produce chemical properties. But is INST an a priori, metaphysically necessary principle? This would be a more controversial conclusion to draw. It is certainly a better candidate for such a principle than those usually proposed by proponents of the Kripke-Putnam framework, but more work is required to determine the full metaphysical implications of the principle. Whatever morals regarding the ‘metaphysical nature’ of microstructural essentialism we draw from the line of thought extending from Paneth, the upshot is that the microstructural version of Natural Kind Essentialism (NKE) and hence Natural Kind Realism are defensible, at least in a somewhat weakened form. If we add certain specifications, as described in this final section with regard to INST^{*}, we can quite easily accommodate standard usage of the term ‘chemical substance’ while retaining an ontologically privileged sense of ‘chemical kind’. This is sufficient for upholding NKE. Microstructural essentialism is of course only one form that NKE could take, but there are historical, empirical, and ontological reasons to give it some further attention, despite the doubts that philosophers of chemistry and others have, quite rightly, recently raised.³⁴

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