



No, water (still) doesn't have a microstructural essence (reply to Hofer & Martí)

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Abstract

Häggqvist and Wikforss (2018) argued that in the case of so-called natural kind terms, semantic externalism relies on an untenable metaphysics of kinds: microessentialism. They further claimed that this metaphysics fails, for largely empirical reasons. Focusing on the case of water, Hofer and Martí *European Journal for the Philosophy of Science*, 9, (2019) rejoin that suitably construed, microessentialism is correct. I argue that their defence of microessentialism fails.

Keywords Essentialism · Microessentialism · Water · Natural kinds · Scientific realism

1 Introduction

Natural kinds are harnessed for many philosophical purposes. They are tasked with warranting induction, offering explanations, and guiding causal intervention. In semantics, the revolution in the theory of reference brought about by Kripke, Donnellan, and Putnam has singled them out for a particular role. The new theory of reference held that the reference of proper names is not determined by explicit definitions or definite descriptions, but that successful reference is possible even if the speaker is ignorant or mistaken about the referent's properties. And Kripke and Putnam argued that the same goes for natural kind terms: what they apply to is not determined by a description, or even a cluster of descriptions; successful reference can occur even in when the user of the term is ignorant or mistaken about the kind to which her term applies.

Moreover, Kripke and Putnam insisted, names and natural kind terms refer stably, to the same thing, across possible worlds – including many where descriptions actually true of the referents aren't true. (Aristotle could have failed to be Plato's teacher; gold could have failed to be yellowish and malleable; but in stating this, we are still talking

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about the individual and the kind, respectively, of which these descriptions *actually* hold.) In Kripke's terms, the idea is that names and natural kind terms refer *rigidly*.

Unlike a proper name, however, a natural kind term applies to many different individuals, quantities, or instances, usually spatio-temporally scattered. So what does "the same thing" amount to here? What remains the same natural kind under counterfactual variation? Such questions have pushed some theorists to abandon the rigidity thesis for natural kind terms (e.g. Soames 2002) and others to hold that kinds are (abstract) individuals (e.g. LaPorte 2004, 2013). But whatever route is taken here, identity criteria for natural kinds remain crucial for the new theory of reference, since even on the view that kinds are abstract individuals, kind terms must have some sort of application criteria for concrete individuals. Enter essences. These serve as same-makers for natural kinds within and across possible worlds. That is, different individuals or samples necessarily belong to (or partake in) the same kind if and only if they share its essence.

Kripke and Putnam held that such essences are microstructural. Häggqvist & Wikforss (2018) argued first that the new theory of reference does indeed rely on microessentialism, and second that microessentialism offers an untenable metaphysics of natural kinds. The reasons why this metaphysics fails, they claimed, are largely empirical. They also suggested that a version of cluster descriptivism appears to offer a semantics better conforming to the scientific facts for many paradigmatic kinds in biology and chemistry.

In a reply in this journal, Hofer and Martí (2019) rejoin that Häggqvist and Wikforss are foisting upon Kripke and Putnam an uncharitably strong and simplistic version of microessentialism, to which Putnam in particular did not subscribe. Hofer and Martí argue that while Kripke and Putnam may have oversimplified matters a bit, they were fully aware of doing so, and moreover the context justified such simplification. The central claim in Hofer and Martí, however, is that there is a perfectly reasonable reading of the microessentialist claim concerning kinds on which it is fully correct.

This debate is relevant to philosophy of science. Beside the interest in natural kinds arising directly from issues like induction, causation, and explanation, debates over the rationality of science, realism, and incommensurability have often explicitly invoked the new theory of reference (apart from Putnam himself, an early and influential instance of this is Newton-Smith (1981)).

In this paper, I will not go into exegesis of Kripke or Putnam. Nor will I discuss the relative merits of competing semantic or metasemantic proposals. Further, while it is not clear that Putnam's and Kripke's metasemantic theory is coupled specifically to *microstructural* essences, this question will not be treated here either. Instead, I will challenge Hofer and Martí's claims for the merits of microessentialism. Like theirs, my focus will be on that staple of natural kind theory: water.

2 Charity, simplification, and structure

Putnam's views on natural kinds and essences changed over time, as did perhaps his views on metaphysical modality (cf. Putnam 2015, Putnam 1983, Wikforss 2013, Hacking 2007). But in Putnam (1975, 224) he did say: "The extension of 'water' ...

is the set of all wholes consisting of H_2O molecules, or something like that". Hoefler and Martí take Häggqvist and Wikforss (and Chang 2012) to task for neglecting the last bit, presumably indicating Putnam's awareness of the intricacy of the details he chose not to delve into (in his 57 page-paper).

Hoefler and Martí are correct that Putnam was aware of simplifying – in “Possibility and Necessity” (Putnam 1983, 63) and “Is Water Necessarily H_2O ” (Putnam 1990), this is particularly clear. But when this is acknowledged, the issue becomes whether the term's extension is indeed “something like that”, or not. Hoefler and Martí argue that it is. Häggqvist and Wikforss think it's not. The issue is thus not with nit-picking over omitted but largely irrelevant detail, as Hoefler and Martí suggest, but rather with whether “the set of all wholes consisting of H_2O ” is even in the right ballpark.

Invoking a little chemistry and philosophy of chemistry, Häggqvist and Wikforss suggested that there is no reasonable sense in which the microessence of water is H_2O , chiefly because the formula doesn't concern microproperties. They also pointed out that while water of course does have structure, there is no such thing as *the* structure of water generally across various conditions and phases (2018, 971). Hoefler and Martí insist, however, that in talking of structure, “ H_2O ” is a pardonable simplification:

Rather than saying that water is necessarily made up of H_2O molecules, Kripke or Putnam might have instead written: “Samples of water necessarily consist predominantly of H_2O [...] molecules, in various polymeric configurations, plus their dissociative products H^+ , H_3O^+ and OH^- , with minor amounts of isotopic compounds such as $H_2^{17}O$, $D_2^{16}O$ (etc.), with the relative concentrations of these components stabilizing into characteristic ranges which depend on temperature, pressure, and the impurities and/or electromagnetic fields present.” (Hoefler & Martí 2019, 9).

And they add: “We find it understandable that they chose not to go into such detail in presenting their semantic and metaphysical claims” (ibid.) I find this understandable too, not least since a complete and adequate enumeration of the microscopic species present in most samples of water might have to be longer than even this ungainly list suggests.¹ The question, however, is whether “ H_2O ”, even when used as shorthand for such a longer catalogue, names a *structure* of water.

Hoefler and Martí think that it does: “... *structure* need not involve spatial, geometric, or even bonding relations. Being composed of two hydrogen and one oxygen atoms is surely a structural property that a molecule may possess” (p. 6, their italics). Although “structure” has no obviously privileged meaning, I think that most chemists would prefer using “composition” at some remove from “structure”. In the special case of a single molecule, and with the explicit invitation to consider one oxygen and two hydrogen atoms, however, the idea here is clear enough.²

But at issue is the structure of water, not of a single molecule, or of a set of molecular (and ionic) species. Talk of structural properties of individual molecules therefore suggests a reading of Hoefler and Martí's claim to the effect that water's

¹ Similar remarks apply to Havstad's (2018) “disjunctive” account of the structure of water.

² Though why structure should in this case abstract away from bonding relations is not so clear.

structure is largely given by describing the structure of individual molecules of which the substance consists. This is probably how many educated laypeople conceive of water at the microlevel – a swarm of little discrete H-O-H particles with neatly uniform bonds at an angle of 104.45°. Such a picture is, however, only accurate for water vapour at <500 °C. As is evident from the block quote above, Hoefler and Martí are completely aware of this. But remember, “H₂O” is now shorthand for a larger variety of individual molecular and ionic species, and the suggestion on the table seems to be that *their* structure is importantly that of water. But is it? That will be discussed in the next section.

First, I just want to note and dismiss another *prima facie* possible reading, on which the suggestion is that a substance’s composition itself is a (sort of) structural property. Hoefler and Martí clearly reject this idea, which they call “implausibly naïve” – so much so, that they think it shouldn’t be attributed to either Kripke or Putnam (p. 5). Perhaps that’s right, although Putnam at least seemed to flirt with such a view in a passage on jade: “Jadeite is a *combination* of sodium and aluminium. Nephrite is *made of* calcium, magnesium, and iron. These two quite different *microstructures* produce the same unique textural qualities!” (Putnam 1975, 241; my italics).³ Whatever Putnam may have held here, Hoefler and Martí – as we saw – explicitly reject the view that composition is structure in the case of substances (although this leaves it a bit unclear why it should be so in the case of single molecule).

3 Microstructure

Philosophical discussion of microessentialism has suffered from a deficit of explicit definitions of the term “structure”. Of course, there is no ban on giving whatever stipulative content one wants (within limits) to this term. But the dialectics of this context places some onus on the microessentialist – who after all, is the one invoking structures to serve as essences – to provide *some* reasonably clear idea of what she means (the complaint that none is offered is made in Needham 2011).

The core claim of essentialism about natural kinds is that kind members are so in virtue of essential properties which are necessary and sufficient for membership. In its original formulation, the claim was that the essential property of chemical substances is a certain microstructure, but still this notion wasn’t defined; if Hoefler & Martí are right, Kripke and Putnam merely figuratively gestured at the intended notion by using compositional formulae like “H₂O”, while critics, including van Brakel (1986), Needham (2000) and Häggqvist and Wikforss (2018) have tended to read them more literally. The force of the critics’ objection, however, wasn’t that on *their preferred* notion of “structure”, the essentialist thesis was wrong, but that on *whatever* notion of structure (save composition), it seems false.

Hoefler & Martí for their part don’t offer a clear definition of what they mean by “microstructure” either – and neither will I. For present purposes we will have to do

³ There may be a reading of this where ‘These’ at the beginning of the second sentence doesn’t refer anaphorically to the compositional affairs talked about in the first. But such a reading seems rather strained.

with a fairly intuitive understanding, probably instilled in most of us from our high school chemistry training.⁴

Operating with some such notion, Hoefler & Martí suggest that at given equilibrium conditions, a body of water has a distinct microstructure:

The natural, equilibrium microstructure of water at given temperature and pressure conditions may be complicated to specify, but it exists and *can* be specified. And because it is stable and reliable, we can now see a clear sense in which K[ripke] & P[utnam] were right on target: water is essentially composed of H₂O molecules, in the stable structural configurations into which such samples evolve with physical necessity for given conditions. (Hoefler & Martí 2019, p. 8; their emphasis).

This suggests that, for each of a variable continuum of pairs of temperature and pressure, there is a single subcompositional structure characterizing each body of water. Not all water is at equilibrium, so perhaps the suggestion isn't that the microstructure alluded to here itself is the essential property, but rather the disposition to settle into some such structure. Still, for the claim to be true, "microstructure" presumably has to be given a liberal meaning, indicating statistically characteristic rates of ions, lengths of polymer chains, rates of association and dissociation, et cetera, rather than a detailed map of constituent atoms (or nuclei and electrons) of the sort given by usual two- or three-dimensional static structural formulae.⁵ For on any such map (if imaginable), bets are that the detailed structure of even water at equilibrium would look quite heterogeneous across different spatial regions of the body.⁶

Even with a liberal reading, however, the claim seems too strong. There is no question that there *exist* a lot of variegated and complex structures, and there may be no particular reason to prohibit the use of the singular here and call it all "a structure", if one likes. But if there is a single, *stable* microstructure of water (at given temperatures and pressures) which exists and *can* be stated, the question arises why it hasn't been stated yet.⁷ The answer seems to be in part that these structures are not fully known or understood yet. Although subject both to intense study and important discoveries, the structure of even just liquid water still remains partly uncharted. As one major authority on the subject wrote: "Of all known liquids, water is perhaps the most studied and least understood" (Franks 1972, 18). Commenting 25 years later, another one wrote: "Understanding the structure of liquid water is certainly not getting any simpler. There seem to be as many different models as authors who have written on the subject" (Jeffrey 1997, 140). Needham (2002) reckons with four competing models for the

⁴ This understanding seems to combine and perhaps conflate bonds and geometrical relations. Hendry (2016) offers a good discussion on why these should be separated.

⁵ I take it that something like this reading is intended by saying, as Hoefler and Martí do, that the structure is "stable and reliable".

⁶ A truly static map abstracting away from dynamics would also be pointless, as well as blurry, given that particle positions would be indeterminate (cf. Needham 2002).

⁷ On an inclusive reading of 'a structure' and a weak enough modality for 'can', Hoefler & Martí's claim that the structure exists and can be stated is surely correct. But since parallel claims about "the microstructure of Borneo" would also be correct, this seems uninformative. The point here is that on stricter individuation criteria for structures, on which for instance "the structure of hemoglobin exists and can be stated" is still true, the claim seems dubious. Thanks to an anonymous reviewer for prompting this clarification.

detailed picture of water alone. Of course, much *is* also known, such as the role of the Grotthuss mechanism of proton transfer (or more accurately, transfer of positive charge via protons) in explaining water's conductivity.

Hoefler and Martí also go on to suggest that whatever microstructure obtains in a body of water (at equilibrium and at a given temperature and pressure) is *subordinate* to the property of being H₂O and derivative from it:

[T]he detailed structural configurations, which vary with temperature, pressure and the presence of trace impurities, are properly seen as being merely the fine-print details. What is most important about water's microstructure, and the explanatory starting-point for understanding the detailed structures ... is simply that water is a substance composed predominantly of H₂O molecules. Much further structural detail follows from this basic structural fact, but the basic structural fact is rightly regarded as essential to being water. (Hoefler & Martí 2019, 8).

A complication here is, again, the fact that water isn't even generally *composed* of discrete H₂O molecules conceived as mereological parts. As for particles, the vast majority of the protons, neutrons, and electrons present in a body of water at any given "moment" – itself a tricky notion in this context (Needham 2002, 220) – do not belong to H₂O molecules, if these are understood to exclude polymers.⁸

But let's move on to the more interesting claim made here, that complex microstructure "follows from" composition. This should be taken as indicating nomological determination: the structure of individual molecules determines, given the actual laws of nature, the highly complex, detailed structures.⁹ It is thus a claim about a certain (nomologically restricted) metaphysical priority, as well as about explanatory priority.

Since Hoefler and Martí admit that these detailed structures vary with different pressures and temperatures – steam and ice are palpably different, and a reflective layperson of any historical period would correctly guess that their difference is due to different structures – and since explanation of detailed structures of water on the basis of structural properties of the simple molecule has so far eluded us, however, awarding the latter such priority seems at best premature. And note that this is not for lack of knowing the relevant laws of nature.

Finally, far from being merely the "fine-print details", the microstructural properties of water are, to the extent they are known, crucial to actually explaining why water has the properties it does. Notably this holds for some of water's more striking characteristics, like its relatively high boiling and freezing points, its conductivity, and the relative density of ice and liquid water.

At the same time, the actual detailed configuration of microscopic species and their interrelations in any given sample, at a specific temperature and pressure, is itself determined by, and so explained by, macroscopic properties like pressure and temperature. And while temperature is reducible, in something like Nagel's sense of intertheoretic reduction, to energy and entropy, it is not reducible to, or explained by,

⁸ Hence, it's not strictly the case that water is composed predominantly of H₂O molecules.

⁹ Thanks to Carl Hoefler for setting me straight here.

kinetic energy of individual microparticles like molecules or ions independently of macroscopic properties.¹⁰

Contrary to Hoefer and Martí, it appears that most of the explanatory structure, in the case of water, resides outside of the simple, single H₂O molecule – especially in the bafflingly complex interactions between particles acting in the (sometimes very long) polymers, and in the interactions between these extremely protean and transient polymers (and oligomers, hydrogen bonds, lattice structures, ion channels et cetera) themselves.¹¹ Whoever holds that such interaction is a mere consequence of the properties of hydrogen and oxygen atoms seems to make a claim well in advance of the evidence, and to take on a heavily reductionist explanatory burden.

4 Hendry's view

There may, however, be a slightly more specific idea guiding Hoefer and Martí's claim that being H₂O underlies or explains the detailed microstructures of water. Variants of this idea are fairly prevalent, I believe, in essentialist theorizing about natural kinds. A major source of inspiration for it is the work of Robin Hendry (2006, 2016, *ms*).¹²

In broad strokes, the idea is this. A compound like water is made up by elements, as indicated by the compositional formula. Similarly, elemental substances like oxygen and graphite are made up of a single element. Elements are individuated by their essential property, viz. atomic number, the number of protons in a single atom. This property determines and explains a range of other properties of (i) single atoms (like mass and electron number and structure, which in turn determine chemical properties), (ii) macroscopic samples of the element (like its characteristic phase ranges, reactivity with other elements, and the detailed structure of such samples, e.g. oxygen being a dimer at standard temperatures and pressures), and (iii) macroscopic samples of compounds containing the elements. In this way, a single determinable property – nicely discrete, since drawn from the natural numbers – of atoms underlies and explains a host of properties and so deserves essential status; moreover, the particular natural number or numbers that are the determinates of this determinable essential property are conveniently conveyed by compositional formulas.

This idea need not require that samples of an elemental substance consist of atoms retaining the structure of an isolated atom. Similarly, samples of compounds need not be held to consist of unmangled molecules of a single kind. An adherent of the idea is thus free to grant that samples of a substance may have many complex and varying structures in different conditions and in various states of aggregation. As Hendry puts it, what makes graphite and diamond both carbon is that they “consist of carbon atoms bonded together in different ways. What is common to them is their being carbon, that

¹⁰ The temperature of a gas may be identified with average molecular kinetic energy only when the molecules satisfy the Boltzmann distribution of energy; but this distribution involves the thermodynamic, macroscopic notion of temperature; hence, no non-circular, reductive identification is available. (See Needham 2010, 167.)

¹¹ And this is of course still a very coarse and simplistic way of putting things.

¹² In sketching this idea, I will partly draw on an unpublished manuscript which Robin Hendry has kindly allowed me to quote, since I find it particularly useful for expository purposes. In doing so I am of course not attributing to Hoefer and Martí any knowledge of, or inspiration from, this text; nor any firm commitment on Hendry's part to what I quote from it.

is, their being composed of atoms with nuclear charge of six” (Hendry ms., 3). Similarly, Hofer and Martí may hold, what makes water in different states of aggregation water is its being “composed of”¹³ H₂O molecules, whatever contortions to, and interactions between, these molecules may occur: for these complex interactions, and the “detailed structures” they give rise to, are just a result of the molecules “[b]eing composed of two hydrogen and one oxygen atoms” (Hofer & Martí, 6).

Much like Hofer and Martí, Hendry (2006) proposes that water is the result of spontaneous interaction between H₂O molecules, provided that the elements – hydrogen and oxygen – persist through persistence of their nuclei; the molecules themselves need not persist in the substance, however, but may be serving as “ingredients” which are used up in the complex processes constantly occurring in the water itself. Hendry (2016, 1077–1078) likewise proposes that what is common to liquid water, steam, and ice is that “each is formed from populations of H₂O molecules”. Here the preposition “from” is crucial. As Hendry stresses, water in most states consists *of* H₂O molecules only if these are taken to be present even when not persisting as monomers, but instead as ingredients “offering ... their parts” (2006, 872).

So how is this structure? Hendry’s view is that it is indeed structure, but only at one, very general, level of abstraction. Structure itself consists of “the relationships among a substance’s parts (at the atomic scale) that remain invariant over specific ranges of physical conditions” (Hendry 2016, 1079). In this sense, structure is abstract, resulting from selective attention to certain relations and omission of others. Hence, what counts as the same structure and as different ones will be scale-dependent, and ultimately interest-dependent (2016, 1079–1080).¹⁴ The notion of structure which Hendry (ms.) describes as “the set of microstructural properties and relations persisting across *all* the conditions in which that chemical substance exists” (my italics) will thus be an extreme limiting case, taking abstraction very far.

But as Hendry notes, there are also perfectly legitimate senses – still abstract, but less general – in which the microstructure of water varies with phase, temperature and pressure, and is highly complex even in a given sample, for a brief time interval, under constant temperature and pressure. On such notions, “structural sameness and difference are temperature-dependent (and therefore energy-dependent) phenomena” (Hendry 2016, 1079).

It is presumably in some such sense that Hofer and Martí themselves talk of “detailed structural configurations”, which in the case of water are today partly understood and partly less so. Some such more demanding sense also seems to be what Needham has in mind when he comments on Hendry’s (2006) offering by noting that “it doesn’t actually give the microstructure of liquid water” (Needham 2011, 16).

Surely structures of this transient kind are crucially involved in actually explaining the properties of a given sample of water, for instance when h-bonding is invoked to explain water’s characteristically high melting and boiling points, or that its dielectric constant is due to the presence of hydrogen cations and hydroxyl anions. (Note that microstructures playing such a crucial explanatory role does not mean that they exhaust

¹³ Where composition is here liberally understood approximately as “what you get fairly shortly after throwing together”, and not in any stricter mereological sense; cf. above.

¹⁴ An anonymous reviewer notes that the scale-dependence of structural variation in general has been stressed by many philosophers of science (e.g. by Ladyman & Ross 2007, Green & Batterman 2017, and Bursten 2018).

any complete explanans, nor that the explanandum reduces to them.) Conversely, saying that such structures (or the ions just mentioned) arise as the result of H₂O molecules being allowed spontaneous interaction may have the merit of being true (for certain fixed conditions), but does not seem explanatory.

5 Scientific realism and microstructure

Hoefer and Martí suggest that microessentialist claims about chemical substances like water are just an expression of scientific realism. Responding to a passage in Leslie (2013), which Häggqvist & Wikforss quote, and which attributes belief in underlying essences largely to psychological biases, they write:

The intuition that such essences exist is a deeply rooted realist presupposition, equivalent to the assumption that an explanation exists for the stable, reliable properties of the many apparently-stable, naturally occurring kinds that we have identified; and that we have already in fact discovered many such explanations. This is not pre-school metaphysics, it's just scientific realism. (Hoefer & Martí 2019, 9).

The sort of explanation Hoefer and Martí have in mind here is one where the putative microessence is the explanans. As a rule, they suggest, “microstructure determines and (together with the laws of physics and chemistry) explains macroscopically observable properties, and does so uniquely” (2019, 10). But it isn't clear why scientific realists should have to commit to such explanatory reductionism. While this allusion to realism in Hoefer and Martí is arguably just an off-hand remark, I would like to end with a few comments on the relation between microessentialism and scientific realism, since these are sometimes assumed to be tightly connected.

Thus, for instance, Tuomas Tahko (2015) has suggested that essentialism about natural kinds – which he takes to be the thesis that natural kinds are mind-independent and defined by their essential properties – is important for defending realism. In Tahko, the idea is that essentialism underwrites the mind-independence of kinds, without which “it would be difficult to support scientific realism” (2015, 797). But it is not clear why a rejection of essentialism in general, and microessentialism in particular, should pose any threat to scientific realism.¹⁵

Anti-essentialists like Needham do not call into question the existence of microentities like molecular, polymeric and ionic species, nor the (at least approximate) truth of theories positing them. Nor is the inductive justification of such theories under suspicion in this context.

Hence all the old worries about the rationality of science, and implied worries about scientific realism – stemming from the purported incommensurability of theories allegedly arising from meaning holism – simply aren't in play here. It may be that

¹⁵ Tahko (2015) distinguishes two theses, Natural Kind Realism (emphasizing mind-independence of divisions in nature) and Natural Kind Essentialism (affirming essences as individuating natural kinds). His claim is that NKR is required by scientific realism, not that NKR entails NKE. But he seems to suggest at least that NKE is the chief way of understanding or supporting NKR (2015, 296).

essentialism in tandem with a causal theory of reference (or even direct reference) would allay those worries, but this is not a good reason to be an essentialist.¹⁶

As for conventionality, there is no credible threat to realism from it either – at least not from anti-essentialism per se. Consider the ongoing debate between Needham and Hendry over the individuation of chemical substances. Needham emphasises macroscopic, chiefly thermodynamic, individuation criteria and rejects microessences (Needham, 2000, 2002, 2011); Hendry insists on microstructural criteria and embraces microessentialism (2006, 2016). Hendry argues that chemical nomenclature (as codified by the IUPAC) sorts substances by microstructure, and that microstructure is crucially involved in “every aspect of a chemical reaction, including the products it yields, how much heat it generates or absorbs, and how fast it happens” (Hendry ms, p. 5). And he argues against thermodynamic criteria, such as Gibbs’s phase rule and the entropic tests, on the grounds that they either cut substance types too finely or too coarsely for “what *chemistry* seeks” in its classifications (ibid., italics original).¹⁷

Hendry also defends the 1923 IUPAC decision, after the discovery of isotopes, to classify elements according to atomic number as conforming to the intentions of earlier chemists, as well as serving the needs of chemistry. On this decision, Needham has commented:

whatever the reason for grouping different isotopes under single *chemical* substances, that doesn’t detract from the fact that they are *different substances*... It is tempting to describe different substances falling under the same kind of chemical substance as physically different although chemically indistinguishable. Whether it is ultimately possible to sustain a distinction between chemical and physical processes, in terms of which such a difference of kinds might be based, is doubtful, however. In the final analysis, it is the difference of substances that is important. (Needham 2002, 213; footnote in original elided).

What is under dispute here is simply whether to classify e.g. heavy water and ordinary water as distinct *chemical* substances. What is not in dispute is that both substances exist, or that they have different properties, or that microstructural properties enter into understanding these properties (as emphasized by Hendry) along with thermodynamic properties (as emphasized by Needham).

Nor is it clear that either party to this debate thinks that chemical properties can be *reduced* to physical properties or even nuclear charge. Indeed, Hendry and Needham have jointly argued that molecular properties, which depend on continuously variable features of chemical bonds, cannot be (ontologically or otherwise) reduced to the discrete property of component elements’ (respective) nuclear charge (Hendry and Needham 2007). But issues of reduction are simply also largely independent of issues

¹⁶ Häggqvist and Wikforss have suggested that there are better ways to allay such worries (2015, 2020). As noted, these issues lie beyond the scope of this note.

¹⁷ As we have seen above, the microstructure Hendry alludes to is mainly to be equated with proton number of atoms of ingredient elements. Mainly, but not exclusively: the differences between red and yellow mercuric oxide depend on the difference in size of lumps of aggregating units of (-O-Hg-O-), but “the differences in lump size are themselves microstructural differences (how many of the repeating units there are per lump)” (Hendry ms., p. 8). This wider notion of microstructure for classificatory purposes is also urged by Bursten (2014).

of realism in this context, where it is common ground that atoms, molecules, polymers et cetera do exist and have such properties as chemistry ascribes them – much along the lines of Hofer and Martí's own preferred form of scientific realism (see Hofer 2020, Hofer & Martí 2020).

So while there may be an element of conventionality to the question of where the boundaries of chemical substances should be drawn, or whether it is worthwhile to insist on separating chemical and physical properties, there is no substantive disagreement here over the realities over which to draw them – what the entities are, which properties they have, and how they interact. The larger ontology is common ground, and the very choice of options assumes the acceptance of current theory. As Hendry (2016, 1080) puts it: “It is the selection that is interest dependent, and therefore plural, but we are selecting only among the real.”

A final note on why essentialism is not a prerequisite for scientific realism. Hendry's microessentialism comes down largely to a claim about the explanatory import what he calls microstructure. As he notes (also cf. Strevens 2019), essentialism is best construed as an empirical hypothesis about what explains the inductive fertility of a kind:

its members can be the subject of inductive inferences because they share a property or properties which are necessary and sufficient for membership of the kind. As mentioned earlier, whether or not this kind of explanation should be accepted is the subject of empirical investigation. Since these investigations can end in a number of different ways, identifying different kinds of explanation or concluding that none exists, it seems clear that essentialism is a topic-relative affair (Hendry, ms., p. 4).

This is all unobjectionable.¹⁸ Learning that a certain sort of explanation of inductive fertility of a category is false, we don't *thereby* learn that the kind doesn't exist (although kinds may be jettisoned for other reasons); the possibility of such an outcome shows that a kind believed to have an essence can survive the discovery that it doesn't.¹⁹ But nothing follows from such a discovery about the existence of entities, truthlikeness of theories, or any other concerns dear to various forms of scientific realism.

6 Conclusion

I have raised some objections to Hofer & Martí's (2019) suggestion that Kripke and Putnam were largely right in saying that water's microessence is H₂O. I argued that even on a charitable construal, and given a sophisticated gloss like that provided by Hofer and Martí, this claim is misleading. I also proposed that anti-essentialism in

¹⁸ It does not, of course, address modal aspects of essentialism. Hendry (ms.) suggests that microstructural characterization of substances yields essentialism by specifying the *nature* of, or *what it is to be*, a certain substance; but is not explicit on how this is to give metaphysical necessity. An attempt at this step may be found in Mallozzi (2018) and Godman et al. (2020); another route is suggested by Papineau (2009).

¹⁹ This observation forms the basis of many criticisms of essentialism as a monistic account of natural kinds, from Dupré (1981) to Slater (2015).

chemistry is compatible with – indeed, assumes – most of what goes into a scientific realist attitude to chemistry’s theories and ontology.

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Declarations

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