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ARTICLE

On Chemical Natural Kinds

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Abstract

A critique of LaPorte's views on chemical kinds, like jade and ruby, is presented. More positively, a new slant is provided on the question of whether elements are natural kinds. This is carried out by appeal to the dual nature of elements, a topic that has been debated in the philosophy of chemistry but not in the natural kinds literature. It is claimed that the abstract notion of elements, as opposed to their being simple substances, is relevant to the Kripke–Putnam approach to natural kinds and to some criticisms that have been raised against it, although I do not support the K–P account. The proposed view avoids the traditional microstructuralist approach to natural kinds. The article also addresses the question of whether natural kinds concern metaphysical or epistemological considerations. Recent attempts by chemists to modify the periodic table are brought to bear on the question of classification and consequently on whether the identification of elements is interest dependent.

Keywords Natural kinds · Element · Chemistry · Isotopes · Mendeleev · Putnam & Kripke

1 Introduction

As is well known, the notion of natural kinds in biology is somewhat problematic. Many philosophers of biology now maintain that biological species do not constitute natural kinds, as was formerly believed, but that they should be regarded as individuals (Ghiselin 1974; Hull 1976). One of the motivations for this claim is that natural kinds should somehow be 'eternal', whereas biological species clearly come and go. One of the most strident critics of this view has been Michael Ruse who, among other things, points out that in modern biology it is no longer the case that species appear only once. As Ruse reminds us, modern biologists can construct new life forms using the techniques of recombinant DNA (Ruse 1987).

Nevertheless, I suspect that philosophers would display less disagreement over the question of whether genuine natural kinds exist in chemistry. They would surely be happy to concede that there may be chemical kinds such as water or gold, to cite the two most frequently used examples in the literature. There has been a quite extensive literature

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concerning natural kinds in chemistry and part of the debate has centered on whether one should adopt a micro-structuralist approach or an anti-micro-structural view. Recently Havstad has argued that matters are more complicated and has disputed the view that chemistry provides more clear-cut examples of natural kinds than biology (Havstad 2018).

Accounts of natural kinds in chemistry have generally come in two main varieties. Hendry has argued that natural kinds are determined by microstructure. This is essentially the Putnam–Kripke view (Kripke 1980; Putnam 1990), but one that has been developed by Hendry in a manner that is more sensitive to what actually occurs in chemical practice. This author recommends moving beyond the classical approaches that seek necessary and sufficient conditions for the identification of a particular element for example (Hendry 2015).

The other main account of chemical kinds may be grouped together under the banner of anti-microstructuralist accounts as represented in the earlier work of Needham and from a quite different perspective by LaPorte (Needham 2011; 2012; LaPorte 2004). This approach may roughly speaking be characterized as being one of anti-reductionism, anti-essentialism and based more on macroscopic properties than on microscopic ones. For example, Needham believes that the identification of substances is better achieved by drawing on thermodynamic data than it is by appealing to microstructure. Moreover, some of the recent natural kinds literature has concerned the question of whether microstructuralism can be extended from elements to compounds, mixtures and, in one article, to proteins (Tobin 2010; Havstad 2018). Nevertheless, the present article will confine itself to discussing the simplest case of chemical natural kinds, that of elements.

Among the many other authors who have written on chemical kinds I would also mention Ellis, according to whom,

> chemists have the most obvious examples of natural kinds—the elements—and of the utiity and predictive power of categorization into natural kinds—the periodic table (Vandewall 2007, 909).

Although Ellis' brand of essentialism appears extreme to many philosophers he shares the view with the present author that natural kinds are level specific.[1]

One philosopher who believes that natural kinds may be defended in biology, as well as chemistry, and who has written on these issues is Joseph LaPorte (1996). However, LaPorte opposes the Putnam and Kripke view and takes the approach that kinds are individuated by their names rather than by their microstructure.

In the present article I wish to re-examine what LaPorte has written on chemical kinds before moving on to present a new slant on the question of the elements as natural kinds. Whereas the notion of compounds like water as natural kinds continues to be debated, there is less disagreement, if any, concerning elements as natural kinds since elements may represent the last undisputed natural kind term in the biological and chemical sciences.

The view of elements as natural kinds that I will present has a long tradition within the history of chemistry, and chemistry itself, but has been little discussed in the contemporary literature on natural kinds.[2] The issue concerns the distinction between elements as basic

[1] Vandewall has written a critique of Ellis' views and considers that his chemical essentialism cannot be maintained (Vandewall 2007).

[2] But as I argue below this is not so much a case of importing something new but of recognizing the metaphysical dimension of the scientific definition of elements as elaborated by Paneth and sanctioned by the International Union of Pure and Applied Chemistry (IUPAC).

substances and elements as simple substances which I will explain below (Scerri 2000).[3] Perhaps the only author who has discussed this distinction in the context of natural kinds in chemistry has been Robin Hendry, who uses it to bolster his defence of a micostructuralist account of natural kinds (Hendry 2012; 2015). However, as Havstad has argued, this move can be avoided and it is quite possible to defend a microstructuralist account in a more consistent manner, as she explains in her article (Havstad 2018). Similarly, Bursten presents a view of chemical kinds which is somewhat intermediate between the microstructuralist version and the competing view of it being a matter of reactivity-based individuation.

In my own account I will draw on the above mentioned distinction between two senses of the term 'element' but not with a view to defending micro-structuralism. Indeed I will begin by focusing on the more metaphysical aspects of this distinction, which I take to provide an alternative to the micro-structural doctrine.[4] Epistemological considerations will also be discussed in view of the increasingly prevalent view that natural kinds are interest dependent, as expressed by Reydon and many other authors,

> [t]hus, one of the traditional metaphysical assumptions about what it is to be a natural kind that has shaped much of the philosophical discussion on natural kinds—i.e., that to be a natural kind is to be a mind-independent kind, in contrast to kinds that do depend (much more strongly) on (human) minds—seems to have to be discarded […] (Reydon 2014, 130).

It is my intention to draw on the distinction between the two senses of the term element without entering into the question of a microstructuralism. If anything my account can be considered to fall into the anti-microstrucuralist camp. My reason for taking such an approach is that I consider that the distinction between the two senses of the term element to be completely independent of whether one adopts a microscopic or microstructuralist account of the nature of elements. This is a view that has been disputed from time to time by chemists such as Schwarz who insists on a microstructuralist reading (Schwarz 2007). Meanwhile, the philosopher-chemist Paneth who was the first to bring the dual sense of elementhood to the general attention of the philosophy of science community argues, as I do, against a microstructuralist reading (Paneth 1962; Ruthenberg 2009; 2010; Scerri 2009).

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[3] The terminology of element as simple substance as opposed to basic substance is due to Heinz Post, while he was in the process of translating his father's (Paneth's) now classic article on the nature of elements (Paneth 1962).

[4] Among other recent work on chemical natural kinds, Bursten presents an account which appears to be a compromise between the essentialist and non-essentialist view (Bursten 2014). Stated otherwise, Bursten accepts a strong microstructuralist component to the identification of chemical kinds but resists going fully-microstructuralist. This is because Bursten believes that a structural description, of the atoms of an element for example, must supplement the stipulation that they be identified through their atomic number as Kripke and Putnam would have it. However, it appears that Bursten's concession to the anti-microstructuralist makes for a somewhat watered down compromise. To the present author at least, it seems to be too easy to reach for an intermediate position between the two major approaches to the identification of chemical kinds.

2 LaPorte on Chemical Kinds: Jade, Ruby, Charcoal and Diamond

In recent years Joseph LaPorte has espoused an intriguing thesis concerning natural kinds. Contrary to the increasingly popular view that there are no natural kinds in biology, LaPorte swims against the philosophical tide and asserts that philosophers of science are mistaken in their denial of biological kinds. Against the view that natural kinds are discovered through modern science, à la Kripke and Putnam (K–P), LaPorte claims that scientists refine the meanings of the relevant natural kind terms to make statements such as "whales are mammals, not fish" true rather than false. LaPorte proceeds to extend similar claims to the area of chemical natural kinds with some interesting discussions on terms like jade, ruby, charcoal and diamond.

Here I aim to consider the scientific facts concerning these chemical terms more carefully in order to point out some limitations in LaPorte's view. Then on a more positive note, I go on to support the existence of elements as natural kinds, although in keeping with recent thinking on the subject I will be making a case for the importance of epistemological factors as well as metaphysical ones. Indeed as some authors have suggested it may be more appropriate to consider epistemological issues before turning to those concerning metaphysics (Reydon 2014). Although I broadly support the K–P line, that elements may be identified through their atomic number, I will have more to say on the question on what sense of the term 'element' is picked out by atomic number.

To return to my opening remarks, I defend natural kinds in chemistry but without appealing to a microstructuralist account. This may appear to be a contradiction since I am expressing support for the view that elements are identified through their atomic number. Some readers may be puzzled by this claim, believing that the very mention of the term atomic number implies a microstructuralist point of view. This is not the case however, since the measurement of atomic number can be carried out using X-ray spectroscopic techniques that were pioneered by Henry Moseley, who was responsible for introducing this quantity as an experimental means of identifying elements (Moseley 1913).[5] On a related matter, Mendeleev readily drew on the concept of atomic weight whereas he did not believe that atoms were real (Scerri 2007). In some instances he preferred the term elemental weight. One might therefore similarly speak of element number rather than atomic number.

2.1 Jade

The example of jade appears in the writings of Putnam who goes to some length to stress how it differs from his own discussion of Twin Earth and whether one should consider the imagined substance XYZ as water or not. The term 'water' is applied by speakers on Earth to the substance having molecular formula H_2O. If these speakers then find a substance with apparently identical properties and with formula XYZ on Twin Earth should they call it water or not? The K–P response is that they should not do so in spite of its apparently identical properties. For Kripke and Putnam it is microstructure that determines extension, not the macroscopic descriptive properties of substances.

[5] As I have argued in a recent article, the person responsible for conceiving of atomic number was the Dutch econometrician, Anton Van den Broek (Scerri 2018).

The case of jade is altogether different according to Putnam. In this case Putnam says there was no new discovery which required a decision as to what name should be used since ‘jade’ was used for long periods of time for two different substances with different molecular compositions.

But LaPorte disputes Putnam’s report of the empirical information on jade. Contrary to Putnam, LaPorte argues that the term jade was applied to a newly discovered substance with a microstructure which differed considerably from the original substance known as jade.[6] LaPorte considers this as a clear counter-example to the K–P line according to which natural kind terms are determined by empirical discoveries of scientists. LaPorte begins with the following claim,

> [t]he Chinese relationship to jade, or “yü”, as they call it, is more interesting than Westerns’ relationship to the material, so I will devote most of my attention to the Chinese term ‘yü’. For the Chinese jade has enjoyed something like the status gold has enjoyed in the West. The Chinese consider jade to be the most precious of material substances, more precious than gold, as a Chinese saying indicates: “One can put a price on gold but jade is priceless.” In contests of skill in ancient China the victor received a scepter of jade, not gold; the second-place competitor received a scepter of gold […] (LaPorte 2004, 95).

Now according to modern science the material that was called jade by the Chinese, (or yü) has the chemical composition of $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$ and the mineral name of nephrite. After thousands of years during which the Chinese had worked with nephrite, as LaPorte reports, a mineral with a very similar appearance but a completely different composition began to surface in China at the end of the eighteenth century. About one hundred years later, Damour, a French mineralogist, determined the composition of this new material to be $NaAl(SiO_3)_2$ and coined the name jadeite.

LaPorte claims that although the Chinese have periodically used terms like kingfisher jade and new jade for this material, they have nevertheless come to regard the new material as genuine jade. Alternatively stated, the possession of common macroscopic properties of the two substances implies to some people that they share the same identity and hence that they can rightly share the same name.

> Would speakers accept the new kingfisher jade as true jade? Yes, they would. They have. Significantly, the Chinese have come to accept jadeite as true jade. ‘Yu’ and ‘jade’ both apply clearly to jadeite as well as to nephrite. True jade includes and is limited to nephrite and jadeite (LaPorte 2004, 96).

LaPorte also describes the situation regarding ’jade’ in the West, which he claims to be more complicated. He points out that nephrite and jadeite have been known in the West although not over such long periods of time as in China. LaPorte concedes that there was some effort to refer to jadeite by a different name following Damour’s discovery of its having a different composition from nephrite. However his conclusion is that even in the West the term jade is also generally used to refer to both minerals, nephrite and jadeite.

But perhaps LaPorte may be overlooking one rather important aspect of the K–P stipulation of natural kinds in connection with what scientists discover. The fact that the Chinese, and some other mineralogists, failed to adhere to the scientific discovery concerning

[6] In fact LaPorte seems to be arguing for an alternative composition rather than microstructure, a point that has been discussed in detail by Paul Needham but which will not be pursued in the present article.

the different composition of jadeite and that they continued to refer to jadeite as jade is somewhat beside the point.[7]

Whereas a layperson identifies a substance through its observable macroscopic properties, the scientist does so through its discovered microscopic properties. In the final analysis both approaches trade in descriptions even if the scientific one is claimed to be an essential description.

The mere fact that some mineralogists have been inconsistent from a scientific point of view is a matter of historical fact from which, I believe, it would be a mistake to draw grand philosophical conclusions concerning natural kinds and how they are to be identified. I prefer to regard the K–P stipulation for natural kinds as a normative recommendation rather than being descriptive of the behavior of speakers of natural languages. Kripke and Putnam are suggesting that the ideal way of identifying natural kinds is for speakers to defer to recent scientific discoveries. They are not proposing that speakers from all cultures have in fact behaved consistently in this manner.

2.2 Ruby

The discussion of another gemstone, ruby, as given by LaPorte is somewhat analogous to that of jade but appears to point to the opposite conclusion, a fact that LaPorte considers as further supporting his view of kind terms.

> 'Ruby' is a venerable term that has long been used for the mineral that is the chemical compound Al_2O_3. Earlier speakers did not know this composition; they managed to identify the stone by its superficial properties, one of which was its red color. The original meaning of 'ruby' was *red*. Eventually scientists revealed the composition of rubies. At that time, late in the eighteenth century, mineralogists were surprised to learn that this mineral comes in *blue* and other colors, as well as red … A few impurities cause color variation. One might expect, then, that 'ruby' would be applied to the blue stones. But it was not. When it was eventually realized that the things called "ruby", all of them red, were specimens of a mineral that comes in many colors, people nonetheless continued to reserve 'ruby' for the red specimens of the material (LaPorte 2004, 101).

LaPorte further claims that,

> [s]peakers were able to continue to call only red stones "rubies" not by ignoring science but rather by interpreting 'ruby' as a name for a mineral *variety* instead of an entire species (LaPorte 2004, 102).

But how can LaPorte assert so confidently that speakers in this case did not simply ignore the scientific knowledge of the day? Perhaps if the speakers in question had adopted something akin to the K–P approach to natural kinds they might have taken more notice of scientific discoveries. They might then indeed have referred to stones with other colors as rubies. Admittedly, LaPorte concedes that the word 'ruby' is strongly suggestive of the color red, and that this may have accounted for the speakers not adopting the same attitude as they did in the case of the name jade, that is not associated with any particular color. But surely the mere fact that two similar cases such as those of jade and ruby should have led

[7] LaPorte tries to anticipate my objection but appears to dismiss it rather lightly.

to different forms of naming, one a liberalization of the term, and the second case a restriction, illustrates the fickleness of speakers of natural languages and nothing more profound than that.

Needless to say, it is not only mineralogists and other speakers of natural languages who behave inconsistently regarding scientific discoveries and scientific terminology. Even among scientists themselves the question of terminology is fraught with difficulties caused by a lack of uniformity in the way in which terminology is applied. For example, in spite of the fact that the International Union of Pure and Applied Chemistry (IUPAC) has established a detailed system of systematic nomenclature for all chemical compounds, one still encounters large numbers of chemists who display no willingness to conform to this systematic nomenclature. For example, the common organic compound CH_3COOH is systematically named as ethanoic acid in order to emphasize that it contains two carbon atoms from the root name *ethan-* as in ethane or C_2H_6.[8] Nevertheless, this compound is regularly referred to by its older common name of acetic acid by chemistry professors and industrial chemists alike. None of these human inconsistencies regarding the naming of putative natural kinds have any philosophical significance as far as I can see.

2.3 Charcoal and Diamond

Another case considered by LaPorte is that of charcoal and diamond. Here we move away from chemical compounds to the case of elements, which will allow me to eventually come to my own view regarding what I called the last standing natural kind term.

> After the discovery of the chemical composition of charcoal, scientists hardly expected the composition of this humble substance to be shared by any impressive material. But chemists were surprised by what they found after investigating diamond (Dietrich and Skinner 1901). Amazingly, diamond's chemical composition was found to be *exactly the same* as that of *charcoal*. Still we do not say that diamonds are charcoal or vice versa, or that these are two varieties of a single species. Rather we say that something besides chemical structure[9] matters to what counts as a member of the substance charcoal (LaPorte 2004, 101).

Here LaPorte would appear to have hit upon an important feature that is not covered by the K–P approach to natural kinds as it applies, or rather fails to apply to allotropes of elements. Charcoal, or perhaps we should more accurately say graphite, and diamond, are both forms of pure carbon. They are composed of carbon atoms, all of which have an atomic number of 6, but bonded in quite different ways. Whereas graphite consists of planes of hexagonally bonded carbon atoms which allow easy slippage between planes, the extremely hard nature of diamond is derived from its highly regular tetrahedral bonding

[8] The tendency to retain common names for chemical compounds is greater in the US where one also frequently encounters the names acetylene for C_2H_2 and ethylene for C_2H_4. The present author who studied high school chemistry in the late 1960s and early 1970s, in the UK, was expected to know the systematic names of ethyne and ethane respectively for these two compounds.

[9] Surely LaPorte means to say "same composition" here, not "same structure". Diamond and graphite do not have the same structure. It is by introducing the difference in structure, perhaps in the manner recommended by Bursten, that one can make sense of the difference between these two allotropes of carbon.

between carbon atoms. In diamond there is one giant lattice which does not allow for any form of plane slippage.[10]

In cases of elements which show allotropy, and there are many others in addition to carbon, the application of the K–P approach does not allow one to distinguish between the allotropes of a particular element. Oxygen for example can be diatomic, as in the more common O_2 molecule, or tri-atomic as in the case of ozone or O_3. Without a further stipulation of the structure of the molecules in question, or the atomicity in the case of oxygen, the identity of the substance is not sufficiently stated, or so it would seem. One response would seem to be that one must also take structure into account, as Bursten argues (Bursten 2014). However, one possible outcome of adopting this approach is that it runs the risk of playing into the hands of the microstructuralist. Bursten denies such concerns by saying that she prefers the notion of *grounding* in microstructure rather than the question being fully determined by microstructure.[11]

I propose to take a more radical approach that makes no concession to the microstructuralist view. What LaPorte does not seem to recognize is that the allotropes of an element are regarded by chemists as 'simple substances', even if they hardly ever make this point explicitly. That is to say, allotropes represent the sense of the term 'element' which may actually be isolated. Chemists have also historically recognized another sense of the term element as 'basic substance'. The origin of the latter sense can be traced back to the Ancient Greek philosophers, as being the abstract bearers of properties, which are themselves devoid of properties. A great deal has been written about this issue and it is not something that I propose to discuss here in any depth (Paneth 1962; Scerri 2000). For the present purposes I will present a brief summary of the views of Mendeleev and Paneth on this question. I will then proceed to argue that the more fundamental view of elements as basic substances is highly relevant to the question of elements as natural kinds and that it is fully consistent with the modern scientific definition of an element in terms of its atomic number.

If one were attempting to rescue at least some aspects of the K–P approach to natural kinds, one could focus on elements as basic substances and not as simple substances. Under these conditions one would *not* need to distinguish between the allotropes of any particular element. This is precisely because all the various allotropes correspond to exactly the same natural kind when we direct our attention to the element as a basic substance. This would mean that objections to the K–P scheme that are framed in terms of the existence of allotropes, would be irrelevant to the discussion of the essences of elements. In addition, as I shall argue, the arguments that have been made by various philosophers in terms of the existence of isotopes of any particular element are likewise irrelevant if attention is restricted to elements as basic substances as I believe it should be (Zemach 1976).

[10] In fact there is now known to be a third allotrope of pure carbon, the or C_{60} molecule, called buckminsterfullere.

[11] Bursten claims that she is not playing it both ways in embracing the microstructuralist as well as the macroscopic/descriptive approach. She argues that whereas the traditional micro-stucturalist bases her identification of a kind entirely on microstructure, she proposes to merely ground her own account on microstructure as supplemented with information regarding structure. I for one am not convinced by this move and suggest that Bursten is taking the 'middle path' and therefore essentially avoiding the question of microstructuralist versus anti-microstructuralist.

3 Are Natural Kinds Mind-Dependent and so Relative to Our Interests?

My quick answer to this question is that they are relative to our interests and that epistemology thus enters the discussion of natural kinds, but not for some of the reasons that have been proposed in the literature thus far, or so I will argue.

A considerable amount of attention in the modern debate concerning natural kinds has been focused on the question of whether kinds are interest dependent (Khalidi 2013). LaPorte is just one author, among many who believe that they are, given what I have summarized concerning his views on jade, ruby etc.

In the wider debate authors like Khalidi have analyzed precisely what it means for a natural kind to be interest dependent. I will draw from this author's writings since he includes some examples of chemical elements as well as compounds. For example, Khalidi asks whether the element with atomic number 111, or roentgenium, should be thought of as mind-dependent, since it does not occur naturally but has been artificially synthesized.[12] This fact would seem to indicate that element 111 is partly a product of the mental activity of scientists. However, as Khalidi clearly recognizes, this argument in favor of the mind dependence of certain elements is not too worrysome to realists who deny any form of interest or mind dependence. As this author writes,

> There do not seem to be principled grounds (apart from mind-dependence) for saying that although uranium is a real kind, roentgenium is not. The fact that atoms of the latter kind were produced as a result of human ingenuity in the lab does not give us a reason for privileging one over the other. After all, helium atoms produced as a result of nuclear fusion in the hot core of a star are indistinguishable from those produced in a controlled fusion reaction […] (Khalidi 2013, 227).

There is another response to those who claim that the kind element might be mind dependent because of the existence of synthetic elements, and one which applies to the vast majority of elements. If the claim is that the mind enters the stipulation of elements because some of them have been synthesized, one could also maintain that mind more generally enters the picture since the vast majority of elements must be extracted form their ores before they can be said to be instatiated. Extraction is no less mind dependent in this respect that artificial synthesis would seem to be. The only elements that this argument does not apply to are those that occur naturally in an uncombined form, such as gold and silver that at one time could be picked up off the floor, so to speak. The vast majority of elements have to be extracted either by the classical means of reduction using some form of carbon such as charcoal or by electrolysis in cases like sodium and chlorine.

However, all this talk of extracting elements refers to what philosophers of chemistry and some reflective chemists have variously referred to as the isolated element or the element as a simple substance. As already mentioned, there is another understanding of the concept of element as an abstract concept, or Grundstoff, that underlies the chemical behavior and properties of any paricular element. In some of the contemporary literature this second sense of 'element' has been somewhat unfortunately translated, as element as basic substance (Paneth 1962).[13]

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[12] Similar questions are raised by Bhushan and Rosenfeld concerning the distinction between naturally occurring compounds and those that are synthesized (Bhushan and Rosenfeld 2000).

[13] This terminology is due to a translation of the German term Grundstoff that according to some authors does not imply any kind of substance whatsoever, since to the scientific community a substance is precisely something that can be instantiated whereas Grundstoff cannot be. The only sense in which Grundstoff can

																														H	He	2
																														Li	Be	2
																								B	C	N	O	F	Ne	Na	Mg	8
																								Al	Si	P	S	Cl	Ar	K	Ca	8
														Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	18
														Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Cs	Ba	18
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	32
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	119	120	32

Fig. 1 The left-step periodic table

It is this latter sense of an element that may be said to persist when an element as a simple substance enters into chemical combination with other simple substances to produce compounds. For example, when sodium reacts with chlorine there is no semblence of sodium the grey metallic matter or chlorine the green gas that can be seen to persist in sodium chloride. What does persist is the Grundstoff corresponding to the elements sodium and chlorine.

4 A More Genuine Form of Mind Dependence of Elements as Natural Kinds

The one sense in which I do believe that talk of elements is genuinely mind-dependent concerns the relationship of the elements to the periodic table. For example, there has been some debate among chemists and philosophers of chemistry as to the possible existence of an optimal periodic table. It is a remarkable fact that in the 150 years since the periodic table was discovered, quite literally over 1000 different periodic tables have appeared in print and digital media (Van Spronsen 1969; Scerri 2020). It is a natural question to ask whether there exists one optimal, or most fundamental, table among all these choices.

However, in asking such a question one needs to consider whether the elements contained in the periodic table are to be characterized primarily through their chemical reactivity or according to physical attributes such as the electronic configurations of their atoms. For example, if one favors placing greater emphasis on electronic configurations, one might support the left-step periodic table as first proposed by Charles Janet in which helium is positioned among the alkaline earth elements (Fig. 1) (Grochala 2018; Scerri 2007; Stewart 2010).

Consequently at least some form of human decision must be taken in seeking the optimal representation of the periodic table. The choice depends somewhat on what audience one might be appealing to, be it chemists or physicists in this case.

Similarly, there has been much debate as to the placement of the element hydrogen within the periodic table. Whereas it is commonly placed at the head of the alkali metals, or group 1, there are grounds for placing it into group 14 or group 17 of the table (Cronyn 2003; Sacks 2006; Scerri 2007).

Footnote 13 (continued)

be regarded as a substance is in the more philosophical sense of the term whereby a substance is a bearer of properties and underlies or subsists below the familiar sensible properties of any element (Earley 2005).

Yet another such case concerns the consitution of group 3 of the periodic table. Whereas the majority of modern periodic tables display this group as consisting of the elements scandium, yttrium, lanthanum and actinium, there are a significant number of authors who replace the last two of these elements with lutetium and lawrencium respectively and place lanthanum and actinium within the f-block of the table (Jensen 1982; Scerri and Parsons 2018). In the final analysis we need to accept that there may not be an optimal periodic table *tout court*.

In all of these disputes, the choice depends ultimately on whether an element is considered primarily according to its chemical behavior or its physical attributes, such as its electronic configuration. In the case of the group 3 debate even further factors must be brought to bear in order to adjudicate between the two options described above (Scerri and Parsons 2018).

5 Discussions on Elements in the Philosophical Literature

Authors who write about kinds in the general philosophical literature frequently appeal to elements in the sense of simple substances that can be isolated while remaining unaware of the by now substanial literature that seeks to broaden the talk of elements to the more abstract sense of the term (Earley 2005; Ghibaudi et al. 2013; Scerri and Ghibaudi, in press).

As mentioned above, I claim that elements that can be extracted fall into the same broad category of elements such as roengenium, that owe their existence to their being synthesized. Whereas the activities of extraction and synthesis to produce elements as simple substances may be said to require the intervension of sentient beings or minds, the existence of elements in the abstract sense does not. As has been argued by many authors, and as will be discussed in what follows, it is this deeper and more abstract sense of element that does the real work in chemistry, in explaining how allotropes and isotopes of elements can be accommodated into the periodic table rather than threatening its validity (Scerri 2012).

The distinction between the two senses of element was held to be very important by Mendeleev and there are many passages in his classic textbook, *The Principles of Chemistry*, in which he goes to great lengths to explain it.

> It is useful in this sense to make a clear distinction between the conception of an element as a *separate* homogeneous substance, and as a *material* but invisible *part* of a compound. Mercury oxide does not contain two simple bodies, a gas and a metal, but two elements, mercury and oxygen, which, when free, are a gas and a metal. Neither mercury as a metal nor oxygen as a gas is contained in mercury oxide; it only contains the substance of the elements, just as steam only contains the substance of ice, but not ice itself, or as corn contains the substance of the seed but not the seed itself (Mendeleev 1891, 23).

Furthermore Mendeleev maintains that it is the elements in the abstract sense, rather than as simple substances, that are the basis for his periodic system of classification of the elements.

Paneth's suggestion is for chemists to take an intermediate position between what he calls naïve realism and a metaphysical view. Paneth claims that in the case of most elemental properties chemists can take a naively realistic attitude. For example, the chemist can regard the ore of mercury, called cinnabar, as simply being red even, though the red color can be reduced to a particlar range of frequencies of reflected light.

On the other hand, Paneth claims, such naïve realism as is entailed in accepting the properties of elements at their face value, cannot be maintained over the question of the persistence of elements in their compounds. In the latter case Paneth maintains that chemist must abandon the naïve realistic view of elements, as simple substances, and should maintain a metaphysical view of elements as consisting of unobservable entities. According to Paneth chemists generally maintain an intermediate position, that is neither full naïvely realism nor a fully metaphysical view, in trying to reconcile the seemingly different ways in which elements behave in different contexts.

6 Can We Identify 'Basic Substances' with Microstructural Components of Atoms?

It is certainly tempting to answer the above question in the affirmative. After all, the nature of basic substances may have been beyond observation in the early history of chemistry when only macroscopic properties could be observed. The quantum mechanical explanation for chemistry, and more specifically for the periodic table, is largely successful. Is it reasonable to therefore suppose that modern chemistry and physics have succeeded in identifying Grundstoff, or basic substances, and that they are the familiar proton, neutron and electron, the number of which distinguish the various elements and their isotopes?

Such an identification would enable one to interpret Paneth's writing on basic substances in a more concrete microstructural fashion and might avoid any apparent mystification. Paneth himself was well versed in the microstructure of atoms even if he may not have been a practicing quantum mechanician. Nevertheless, he consciously resisted making any microscopic identification of basic substances along the lines suggested above. Quoting one H.C. Hell, Paneth writes,

> ''According to the second definition … the concept of element coincides with that of atom, and serves mainly to designate and individualise the latter more closely… the atoms are the true elements of bodies'', a statement which is not, in my opinion, correct. The atomic theory can, it is true, contribute enormously to—indeed, may be necessary for—visualising how the basic substances persist in simple substances and compounds; but the concept of basic substance as such does not in itself contain any idea of atomism. It was, after all, while explicitly rejecting atomism that Lavoisier carried this concept to victory; and also in more recent times, there were, and are, chemists who avoid the atomic theory but retain the elements, including, of course, elements in the sense of basic substances (Paneth 1965, 133).

To claim that the central mystery of chemistry, namely the question of how elements persist in their compounds, has been fully resolved by the quantum mechanical explanation is to fall into the trap of presentism. I believe it may be more fruitful to resist the reduction of such a philosophical question to one concerning physicalism and talk of fundamental particles.

7 The Question of Isotopes as "Atoms"

The K–P causal theory of reference and its assertion that chemical compounds and elements are natural kinds which can be identified by their chemical formulas and atomic numbers respectively has come under a great deal of criticism by appeal to the existence of isotopes (Zemach 1976; van Brakel 1986; 2000). For example, in Zemach's much cited critique of Kripke and Putnam's theory we read,

> [n]othing that is composed of D_2O molecules is composed of H_2O molecules; yet (Saul Kripke to the contrary) heavy water is commonly regarded as a kind of water. The same holds for aggregates of T_2O, HDO, HTO, and DTO molecules (the number of varieties is eighteen, since in each case the oxygen can be either O^{16}, or O^{17} or O^{18}). All these we say are different kinds of water (Zemach 1976, 120).

Zemach seems to be suggesting that Kripke and Putnam are actually contradicting scientific knowledge by regarding all of these species as simply 'water' contrary to their supposed reliance on science. But on my interpretation, Kripke and Putnam's wish to call all these species as 'water' accords perfectly well with the chemist's sense of water, since for chemical properties the particular isotopes present in the molecule are of no consequence.[14] So in terms of *chemical kinds* I would argue that all of these species are not in fact different kinds of water but simply one chemical kind.[15]

But let us return to discussing elements rather than compounds. As in the case of allotropes I will claim that any critiques having to do with isotopes of gold, or whatever element is chosen, are unfounded. Moreover the view that I present in terms of the abstract nature of elements is not foreign to chemistry but was upheld especially stridently by the person who was the first to define the chemical elements in terms of their atomic numbers in a scientific context, namely the chemist Paneth.[16]

In the 1920s Paneth drew on the notion of elements as basic substances in order to save the periodic system from the major crisis that it was facing. Over a short period of time many new isotopes of the elements had been discovered, such that the number of 'atoms' or most fundamental units suddenly seemed to have multiplied. Should the periodic system continue to accommodate the traditionally regarded atoms of each element or should it be restructured to accommodate the more elementary isotopes that might now be taken to constitute the true 'atoms'? Paneth's response was that the periodic system should continue as it had done before, in that it should accommodate the traditional chemical atoms and not the separate isotopes of the elements. Paneth was recommending that chemists should uphold the notion of elements as basic substances rather than attempting to restructure the periodic system to accommodate the newly discovered simple substances in the form of isotopes. As in the case of allotropes this represents a situation where one element, in the

[14] Hacking has emphasized the differences between Kripke and Putnam's versions of what I am calling the Kripke-Putnam theory. For the purposes of this article I will however maintain the common practice of lumping these two approaches together (Hacking 1991).

[15] A fuller discussion of this issue would necessitate examining how one makes distinctions between chemical and physical properties which to my mind is a largely unproductive exercise.

[16] Some readers may believe that this step was taken by Moseley or even Van den Broek (Scerri 2018). However, although the role of atomic number was first elaborated by these researchers it was Paneth who first gave the modern definition of a chemical element using the concept of atomic number (Kragh 2001).

sense of the basic substance carbon, for example, gives rise to several different simple substances, be they allotropic forms or isotopes of the element.

Paneth and Hevesy went further by providing evidence in support of this choice for chemists.[17] They were among the first chemists to show that the chemical properties of isotopes of the same element were essentially identical.[18] Chemists could therefore maintain the elementary nature of atoms of the same element while conceding that such atoms could occur as different isotopes.

Paneth's recommendation that the chemist's periodic table should be retained was based on the notion of elements as basic substances and not elements as simple substances. Had chemists focused on simple substances they would have had to accept the new 'elements' that were rapidly being discovered in the form of isotopes. While choosing to ignore these 'elements', that were really isotopes, in favor of abstract elements, chemists were able to uphold the notion of chemical natural kinds, as entities that occupy a single place in the periodic system.[19]

A more graphic understanding of the situation may be obtained from considering the occupants of each of the spaces of the modern periodic table. Given that most elements display a variety of isotopes it should be clear that the 'atom' that is being depicted in each space is not in fact a physically realizable atomic entity except in the few cases of elements that show just one isotope. Instead the place reserved for chlorine, or oxygen, to cite two examples, should be regarded as occupied by an abstract atom of each of these elements.[20] The ordering and classification of the elements in the periodic system operates at the level of ignoring any differences between isotopes of any element.

8 Back to Natural Kinds

I claim that natural kinds are level specific, and this may be another example of the 'intrusion' of epistemology. What I mean is that each of the sciences, operating at a different hierarchical level, has its own set of natural kinds. Physics, chemistry and perhaps even biology each possess natural kinds which may cease to behave as such when viewed in a reductive manner.

Similarly, as Van Brakel has written, one can identify other forms of levels such as molar, molecular and quantum mechanical or even what can be seen with the naked eye as opposed to what requires a microscope (Van Brakel 2012). Furthermore, there may exist more levels within broader levels such as chemistry and physics, namely physical chemistry. As this author also points out properties such as boiling points cannot easily be assigned to either of the major levels of chemistry or physics.

[17] Paneth and Hevesy showed that the electrochemical potential from two cells made from different isotopes of the metal bismuth was the same as far as experimental techniques of the day could distinguish (Scerri 2000).

[18] The fact that more recent research has revealed some differences even in the chemical properties of isotopes does not alter the central issue under discussion.

[19] Recently Brad Wray has argued that the discovery of isotopes and the change from using atomic weight to using atomic number to characterize elements represented what he calls a "classic Kuhnian revolution" (Wray 2018).

[20] These physically unrealiseable atoms have an atomic weight that is the weighted average of the weights of all its isotopes. All these isotopes share the same atomic number but they are different entities depending on their weights.

The atoms of the different elements each reduce to a collection of a particular number of protons, neutrons and electrons when appropriately reduced to their elementary particle components. This does not negate the fact that, at the chemical level, atoms can be said to exist as natural kinds in any element, such as gold, silver or mercury. The view that natural kinds are level specific in this manner amounts to claiming that natural kinds depend on the particular interests of scientists. A question which has been traditionally regarded as being ontological must therefore admit an epistemological aspect.

Chemistry thus possesses the natural kind element even though reduction via elementary particle physics destroys the distinctness of each of the elements by reducing them to a pile of protons, neutrons and electrons. Similarly one ignores the discovery of isotopes and the fact that they possess different weights in maintaining the validity of the periodic system of the 'elements' rather than attempting to construct a periodic table of the isotopes.[21] The development, and the continuing survival of the periodic table, as a means of organizing much of chemistry represents an epistemological move and is not fully determined by the way that matters might exist in the world independently of human knowledge.

9 Are Classifications About the Way the World Is or Are They About Our Interests?

As mentioned above, because I consider natural kinds to be level specific, in that chemistry has its natural kinds and physics has its own natural kinds, I support the view that natural kinds or the classification of scientific entities are interest specific.

To consider one much discussed example, there is an ongoing debate among chemists regarding the placement of the element helium within the periodic table. This element is usually regarded as a noble gas because of its extreme inertness and it is therefore placed among the other inert gases in group 18 of the periodic table. However, in terms of its electronic configuration the helium atom possesses two electrons and can therefore be placed among the alkaline earth metals such as magnesium and calcium whose atoms have two outer electrons (Fig. 1). Such a repositioning of helium is indeed carried out in some periodic tables that appear in physics books and in some spectroscopic periodic tables (White 1934). Moreover there has been a good deal of more recent discussion among chemists and philosphers of chemistry as to the virtues of placing helium in the alkaline earth group (Grochala 2018; Scerri 2020; Stewart 2010).

The response of many chemists to this question is that the representation of the elements depends on one's particular interest and that there is no such thing as one correct periodic system within any particular domain such as according to electronic structure. I believe this to be an essentially correct position but one that should not prevent us from seeking the best possible or most fundamental form of the periodic system.

For example, one may still seek to achieve the best possible representation based on electronic properties or alternatively on the chemical reactivity of the elements. Within a particular area of interest, questions regarding the placement of elements like hydrogen or helium are therefore genuinely scientific, as is the much debated question of the make-up

[21] Whether the discovery of isotopes is regarded as part of physics or chemistry is beside the point. The point is rather that in discussing natural kinds one needs to stop at a certain point in the reductive hierarchy, otherwise all putative natural kinds eventually dissolve into mere fluctuations in the quantum mechanical vacuum.

of group 3 of the periodic table. The latter consists of a long-standing debate, as mentioned in Section 3, as to whether group 3 of the periodic table should consist of the elements scandium, yttrium, lanthanum and actinium or whether the last two of these elements should be replaced by lutetium and lawrencium (Jensen 1982; Scerri and Parsons 2018). The admission of epistemological aspects in the form of particular human interests does not diminish the over-arching urge for scientists to obtain increasingly accurate descriptions of the elements and the relationships among them.

10 Conclusions

The question of whether natural kinds are to be discussed in metaphysical terms, or not, has been examined by a number of authors in the natural kinds literature. Van Brakel for example dismisses the possibility of a metaphysical understanding of natural kinds (van Brakel 1986; 2000; 2005; 2012).

Meanwhile Mellor seems to believe that the K–P account of natural kinds is inherently metaphysical when he writes,

> [t]he necessity of essential properties is metaphysical, not epistemic. The claim is that things of a kind have its essential properties in all possible worlds, not that its essential properties are knowable a priori. In particular it is not supposed to be analytic to ascribe its essential properties to things of a kind. Kinetic theory gives the essence of temperature, not the meaning of 'temperature' (Mellor 1977, 300).

In the present paper it has been argued that the K–P account of natural kinds, as it concerns elements in particular, can be defended against many of its critics precisely by appeal to the metaphysical notion of elements as basic substances. Moreover, this notion has been historically important in such cases as Mendeleev's establishment of the periodic system and Paneth's resolution of how to consider the periodic system in the light of the discovery of isotopes.

I do not necessarily support the K–P approach to natural kinds but have attempted to clarify some of the previous criticisms based on isotopes and allotropes, which I take to be misplaced. I also acknowledge some serious problems which have been raised against K–P, especially the *qua* problem as discussed by Devitt and Sterelny (1987) and more recently by Stanford and Kitcher (2000). To put the issue simply, it may be one thing to say that the essence of gold resides in its having atomic number of 79. However, in trying to convey this fact to other speakers, while pointing out a sample of gold, we need to convey that we are pointing to a sample of gold rather than a sample of any metal, or any solid for that matter.

According to these authors we cannot quite do away with a descriptive or nominalist component in trying to specify natural kinds. Here too I believe there may be an interesting analogy with the scientific situation regarding elements. Although the work of Mendeleev, Paneth and others shows the need to focus principally on elements as metaphysical entities rather than as simple substances, it would be foolhardy to believe that simple substances can simply be jettisoned! After all, the whole of modern chemistry, starting with Lavoisier, has involved carrying out experiments on simple substances of various kinds that can be isolated rather than just speculation on the abstract elements as bearers of properties.

Although the similarity between the elements in any group of the periodic table should be located at the level of elements as basic substances, the usefulness of the periodic table is that it also guides us in the chemistry of the elements as simple substances that can be isolated and experimented upon.

The question of mind dependence in discussions of natural kinds has increasingly come to the fore and the currently received view is that epistemological aspects need to be considered when invoking natural kinds. Any form of pure essentialism as envisaged by Kripke, Putnam and others is now considered to be an inappropriate way to characterize natural kinds (Ereshefsky and Reydon 2015).

In the present article various possible form of mind dependence of kinds have been reviewed. First, LaPorte's analysis of how speakers of Chinese used the word "jade" to refer to two different substances was examined and found wanting if elements are viewed in the deeper sense that distinguishes between basic as opposed to simple substances. Another possible form of mind dependence that invokes the existence of synthetic elements was also deemed unimportant given that the vast majority of elements need to be extracted, which is clearly a human activity and hence mind dependent in a trivial sense.

A stronger form of mind dependence was discussed in the context of current debates among chemists regarding the classification of certain elements. This last form of mind dependence was deemed to be genuine and not to be dismissed as in the case of two categories mentioned above. We conclude that mind dependence is a genuine feature of how chemists regard the elements as natural kinds. The admission of epistemology into such questions does not diminish the underlying urge on the part of scientists to obtain increasingly accurate classifications of the elements and the relationships among them. Finally, our discussion of elements as natural kinds does not consist of a microstructuralist approach but relies on the understanding of the concept of an element that was provided by Mendeleev and Paneth and now revived by contemporary philosophers of chemistry.

Moreover, the views expressed in the present article pertain specifically to chemical kinds. Whether they have any impact on discussions on kinds in general is a question I leave to others. All I would add, is that in discussing chemical kinds we can at least be confident that many of the complications that arise in the biological, and more specific sciences, can be avoided.

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