

Why there is no salt in the sea¹

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Abstract

What, precisely, is 'salt'? It is a certain white, solid, crystalline, material, also called sodium chloride. Does any of that solid white stuff exist in the sea? — Clearly not. One can make salt from sea water easily enough, but that fact does *not* establish that salt, as such, is present in brine. (Paper and ink can be made into a novel — but no novel actually exists in a stack of blank paper with a vial of ink close by.) When salt dissolves in water, what is present is no longer 'salt' but rather a collection of hydrated sodium cations and chloride anions, neither of which is precisely salt, nor is the collection. The aqueous material in brine is also significantly different from pure water. Salt may be considered to be present in seawater, but only in a more or less vague 'potential' way. Actually, there is no salt in the sea. In both ancient and modern treatments of other important chemical concepts, including the notions of 'element,' related complication, especially polysemy (terms with multiple meanings), also occurs.

In a recent paper, Paul Needham discussed the (predictable) properties of chemical substances, phases, and solutions. He provided a valuable characterization of cases in which several quantities occupy the same space. He also concluded that solution properties are not 'intensive,' because solvent and solute do not have parts in common. He tacitly assumed that ingredients are not altered by their inclusion in a solution. This may be the case in some special cases (deutero-benzene dissolved in benzene, say) but is not true in general—and certainly does

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Running head: Why there is no salt in the sea

not apply to the case of brine, which Needham used as an example — since the ions that exist in the solution, and also the aqueous material there, are quite different from the pure ingredients used in making the solution. An adequate theory of wholes and parts (mereology) must take into account that when individuals enter combinations of interesting sorts they no longer are the very same individuals that existed prior to the composition. It appears that no such formal theory now *actually* exists.

(End of Abstract)

I

When ingredients are combined to produce something new, do the constituents remain in the combination? If they do persist, how do they do so? This set of questions has been considered by many philosophers as the problem of *mixis* (mixis), the Greek word for combination. (Philosophers frequently translate *mixis* with the English word 'mixture,' but chemists use the term mixture with a different meaning.) The examples of *mixis* discussed by philosophers, both ancient and modern, are generally the sorts of materials that concern chemists (e.g., water, salt, iron, rust, brine). During the past century, chemical science has attained a remarkably detailed understanding of what holds constituents together in solutions and in chemical substances. It might seem that all philosophical confusion ought to have been cleared up by that scientific progress. But serious philosophical problems persist, some of them connected with fundamental features of chemistry.

In a lecture at Königsberg in 1931, the eminent German chemist Fritz Paneth claimed that, as used in contemporary chemistry, the word 'element' has a *double meaning*—this single word has two quite distinct connotations (Paneth, 1962, 2003). This is what linguists call 'polysemy.'

In the German-language original, Fritz Paneth used the words *Grundstoff* and *einfacher Stoff* for the two alternative meanings of the term 'element.' The translator (F. Paneth's son, H. R. Post²) rendered³ these designations into English as 'basic substance' and 'simple substance.'

² He anglicized his family name on relocating to England.

Running head: Why there is no salt in the sea

Using this vocabulary, the element chlorine (as Cl₂, the gas sometimes called 'dichlorine,' with green color, pungent odor, and poisonous effect) should be considered a 'simple substance.' In contrast, the element chlorine exists in carbon tetrachloride as a 'basic substance' without specific properties. The penultimate sentence in Fritz Paneth's address was translated as:

The concept of element must be taken in its naïve-realistic sense when meaning 'simple substance,' but understood as transcendental⁴ when meaning 'basic substance.'

Eric Scerri⁵ holds that Dimitri Mendeleev's success in developing the periodic table was connected with his subtle use of the double meaning of the (modern) concept of a chemical element. (Scerri, 2000) Scerri avoided using the word 'transcendental' by calling *Grundstoff*, 'abstract element.' More recently (Scerri, 2003) he has used the designation 'element-1' for *Grundstoff* and 'element-2' for *einfacher Stoff*.

A corresponding kind of double meaning can be discerned in the ancient term generally translated with the modern English word 'element.' In Book V of *Metaphysics* (1014^a, 26-35), Aristotle⁶ writes:

We call an element (στοιχεῖον, *stoichion*, 'simple component') that which is the primary component immanent in a thing, and indivisible in kind into other kinds....[T]hose who speak of the elements of bodies mean the things into which

³ The German word *Stoff* used by Paneth does not carry (Buchler, 2001) the same philosophical baggage that the English word 'substance' does. The term 'substance' comes from Latin *substantia* (literally, something that stands under), which derives from ancient grammatical theories (e.g. those transmitted through Priscian, fl. ~ 500 A.D.) and seems to imply a philosophical outlook that would generally be rejected if it were made more explicit.

⁴ Paneth also included a note on the word 'transcendental': "I wish to emphasize particularly that I am using the word 'transcendental' in its epistemological sense only, i.e., meaning 'beyond the sphere of consciousness.'"

⁵ H. R. Post was mentor of Eric Scerri's Ph. D. thesis at the London School.

⁶ Quotations from Aristotle are taken from Barnes (ed.), 1984.

bodies are ultimately divided, while *they* are no longer divided into other things differing in kind; and whether the things of this sort are one or more, they call these elements

But in *On Generation, book 2* [330^a, 30 - 330^b, 25], Aristotle also says:

The elementary qualities (στοιχεῖον) are four, and any four terms can be combined in six couples. Contraries, however, refuse to be coupled; for it is impossible for the same thing to be hot and cold or moist and dry. Hence... the couplings of the elementary qualities are four. And these four couples have attached themselves to the *apparently* simple bodies (fire, air, water, and earth) in a manner consonant with theory. ... In fact, however, fire and air and each of the bodies we have mentioned, are not simple, but combined. The simple bodies are indeed similar in nature to them, but not identical to them. Thus the simple body (στοιχεῖον) corresponding to fire is fire-like, not fire: that which corresponds to air is air-like, not air, and so on with the rest of them. (Emphasis is in the Joachim translation.)

The upshot of this is that, in this work at least, Aristotle holds that the elements are not substances (ousia, οὐσία) with independent existence. According to this reading, elements are no more capable of being isolated than are matter (hyle, ὑλὴ) and form (morphe, μορφή).⁷ The dual meaning of fire, air, earth and water in this text—as both apparently simple bodies and as the properly simple bodies that are ultimate constituents of things—is quite comparable to Paneth's analysis of the polysemy of the modern term 'element.' It might seem surprising that linguistic complexities⁸ are present even in such advanced sciences as chemistry, but the complexity of the

⁷ Contemporary philosophers—even committed followers of Aristotle (Wallace, 1997)—sometimes appear to consider components (elements, matter, form ...) as if they are, or could be, independently existing entities.

⁸ This seems a kinder term than 'confusions' or 'ambiguities', or even the learned term 'amphibologies' employed in literary criticism. (Wood, 2003.)

Running head: Why there is no salt in the sea

world inexorably leads to many such problematic situations. (See Hoffmann, 1995, for a number of examples.)

II

As a part of a long-term project directed toward framing a macroscopic ontology,⁹ Paul Needham recently discussed 'substance properties' (Needham, 2003). A main aim of that paper was to clarify similarities and differences among the kinds of properties that are characteristic of chemical substances (such as salt or water), phases (as ice, water, steam), and solutions (e.g., brine). Needham uses 'property' as equivalent to 'predicate' (Putnam, 1969), rather than employing the more pragmatic understanding of that word that is favored by chemists (Earley, 2003a). Conversely, he usually uses the word 'substance' in the restricted sense of 'chemical substance' rather than in the wider sense that is generally used in philosophy (Reeve, 2000). Ruth Garrett Millikan (Millikan, 2000) has provided a contemporary discussion of the concept of 'substance' (in the sense *not* generally used by Needham):

Substances.... are whatever one can learn from given only one or a few encounters, various skills or information that will apply to other encounters. Further, this possibility must be grounded in some kind of natural necessity.The function of a substance concept is to make possible this sort of learning and use of knowledge for a specific substance..

However, Needham does write (This, and subsequent quotations, are from Needham, 2003.):

The ancients thought that water turned into another substance when it evaporated and into yet another when it froze....

Since the ancients did not have our notion of 'chemical substance,' the word 'substance' in this sentence must have a meaning close to the ordinary philosophic understanding of that word, as discussed by Millikan.

⁹ The present paper is intended as a contribution to that project.

Since Needham seeks to outline an ontology that is completely macroscopic, he avoids all reference to microscopic entities such as atoms, molecules, or ions. Following one standard usage in non-equilibrium thermodynamics (Kondepudi, 1998), he restricts his attention to regions large enough for the macroscopic concept of temperature to be meaningful.

Formally, then, by laying down a general condition ensuring that all quantities are macroscopic quantities, it is not necessary to introduce a spatial restriction on the distributivity condition.....what occupies sufficiently small (spatial) regions is not a substance.

For samples¹⁰ that contain a number of chemical substances as components, further considerations apply:

The question naturally arises of how quantities are related to space. ... although there may be several substances in the quantity, only one volume is specified – the volume of the whole... Accordingly, a mixture may be partitioned into a collection of non-overlapping parts each comprising all and only one of the substance kinds in the mixture. Non-overlapping quantities have no part in common. But the separate (i.e. non-overlapping) quantities in such a partition all occupy the same place.

Needham is particularly interested in whether specific properties of particular samples are (or are not) 'spatially homogeneous' and / or 'intensive.' Spatially homogeneous properties are the same in all (spatial) parts of sample. Intensive properties satisfy two conditions. The first ('distributive') condition is: if predicate *j* applies to *p* and *r* is a part of *p*, then predicate *j* also applies to *r*. The second ('cumulative') condition is: if predicate *j* applies to *p* and, in addition, *j* applies to *r*, then *j* also applies to the summation of *p* and *r*. Needham concludes:

¹⁰ Needham follows current practice of philosophers considering the ancient question of chemical combination by designating such samples as 'mixtures.' From the point of view of current word usage in chemistry, 'combination' would be preferable to 'mixture' as a translation of the Greek *mixis* (*mixis*). H. H. Joachim, the translator of the highly regarded 1922 Oxford English version of Aristotle's *On Generation*, does use 'combination' and related forms for this purpose.

Running head: Why there is no salt in the sea

Substance properties are *intensive but not (spatially) homogeneous*....

Phase properties are *intensive and (spatially) homogeneous*....

Solution properties are *(spatially) homogeneous but not intensive*.

All properties of single chemical substances (e.g., water) fulfill both distributive and cumulative conditions: substance properties are intensive. But single chemical substances may exist in several phases (e.g., liquid water, solid ice, water vapor). Under some conditions, two or more phases of a single chemical substance may coexist in contact. Each phase has its own properties, quite different from those of other phases of the same chemical substance. On this basis, chemical-substance properties are considered to be intensive, but *not* spatially homogeneous.

Each part of a chemical phase has the same properties as every other part. (The distributive condition is fulfilled.) Properties of the phase (as a whole) are the same as the properties of the sum of the parts of that phase (the cumulative condition is also met). Phase properties are therefore *intensive*. Single chemical phases have the same properties in all spatial parts (phases are spatially *homogeneous*).

All spatial parts of chemical solutions have the same properties: solutions are spatially *homogeneous*. But, Needham holds, solution properties are *not* intensive, because solutions have (non-spatial) parts (solvent and solute, say) that have different properties.

Brine is not a substance because any brine has parts that are not brine, such as its water content and so it is not distributive But it is spatially distributive And if all the spatial parts of a region are occupied by quantities that are brine, then the whole region is occupied by brine [—] it is spatially cumulative.

And further:

The salt¹¹ in a brine solution occupies the same place as the brine. Again, some of the parts of the region occupied by the salt are parts of the region occupied by the

¹¹ A footnote at this point in Needham, 2003 reads: 'Or whatever it is apart from water that is present in brine.'

Running head: Why there is no salt in the sea

water in the brine; but the salt and water are separate, and so the parts of the salt in question are not parts of the water.

To the extent that this is the case, the distinction between chemical substances, phases, and solutions has been clarified. But the conclusion that solution properties are not intensive does not seem consistent with the understanding and practice of contemporary chemists. Furthermore, the criteria that practicing chemists use to distinguish phases, substances, and solutions have not been mentioned.

III

It would seem that the practices used by working scientists to distinguish classes of materials should be considered by philosophers developing corresponding distinctions for theoretical purposes. As Aristotle remarked in *On Generation and Corruption* [316^a 6-10]:

... those who dwell in intimate association with nature and its phenomena are more able to lay down principles such as to admit of a wide and coherent development...

Every practicing chemist needs to have information about the purity of the materials he or she uses. The amount and identity of the contaminants in each of the chemicals employed may well turn out to be highly significant for the results of an experiment. Often a chemist will make (synthesize) a particular compound that is not otherwise available. It then becomes necessary to remove contaminants—to 'purify' the desired product in so far as that may be feasible. In such cases, chemists apply sensitive tests to distinguish between substances (pure compounds) and mixtures or solutions (such as the desired compound with various contaminants). In order to do this, chemists routinely submit synthesized products to operations under which the desired product and anticipated contaminants are expected to have different behaviors. Examples of such procedures (among many others) include fractional distillation, recrystallization, and chromatographies of many types. After each application of the selected procedure, some of the properties of the product are measured. So long as any property changes under application of the operation, the product still contains contaminants. Frequently this purification procedure may have to be repeated using an alternative operation, in order to remove contaminants not separated by the operation first used.

Running head: Why there is no salt in the sea

The elemental analysis of a natural material or synthetic product (determination of the percentage of each element that is a constituent of the sample) is an especially significant property. True compounds (chemical substances) are characterized by a specific and constant elemental composition. In contrast, mixtures and solutions vary greatly in elemental analysis and composition, as the ratios of the various components of the sample changes. Permanence of elemental composition (also known as 'stoichiometry')—constancy of elemental analyses under repeated operations designed to remove contaminants—is the criterion that chemists use to distinguish chemical substances from solutions and mixtures.

There is a real difference between materials that have constant analyses (stoichiometric compounds) and materials that do not maintain constant analyses (non-stoichiometric compounds, solutions, mixtures, and aggregates). Lithium aluminum hydride is LiAlH_4 —elemental analysis yields 1/1/4 ratios of the molar amounts of Li, Al, and H. (Such stoichiometric compounds are sometimes called 'Daltonides.') In contrast, titanium hydride is TiH_n —where n can have any value over a wide range. (Titanium hydride is a 'Bertholide.') For some purposes, titanium hydride is best considered as a solid solution of monohydrogen (H) in metallic titanium—for other purposes, the same material is best dealt with as a non-stoichiometric compound.¹² Needham does not make explicit use of the difference between stoichiometric and non-stoichiometric materials.

Table 1 divides what Justus Buchler called 'natural complexes' (Buchler, 1966)—whatever can be encountered in any way—into various categories, according to criteria that are used by chemists. Those un-instructive natural complexes that do not fit Millikan's wide definition of substance are called (for want of a more apposite word) 'happenings.' Among 'Millikan substances,' some are extended in time (continuants): these are called 'entities' or things (*ousia*, in Greek) and processes. Such continuants are contrasted with evanescent (but instructive) 'events.' Chemicals (stuffs) can exist in closed systems with no connection to the rest of the world; 'dissipative structures' are entities that are composed of structures of processes and must exist in open systems, with exchange of energy and materials with the environment (Earley,

¹² The distinction between non-stoichiometric compounds and solutions is one of convenience.

2003). Stuff that retains its properties under operations such as recrystallization are chemical substances, properly so called—if properties vary under such treatment, the sample is a mixture. Some chemical substances can be broken down, into what chemical experience has shown to be 'simpler' materials, by ordinary chemical means (these are called compounds): substances that cannot be so broken down are designated elementary substances. Homogeneous mixtures are called solutions: others are considered mixtures or aggregates. Some compounds (Daltonides) have fixed elemental analyses, others (Bertholides) have variable analyses. Solutions for which all properties are linear in composition may be called 'ideal solutions.' Most real solutions do not come close to having that characteristic. As mentioned above, a number of different elementary substances corresponding to a particular element are called 'allotropes.' Ideal and non-ideal solution and mixtures of allotropes can exist.

TABLE I INSERTS ABOUT HERE

IV

Most chemical species that contain more than a few atoms as components have 'isomers'—different chemical species that have the same elemental analysis. For instance, there are two quite different materials that are properly called 'propyl alcohol': both have the elemental analysis corresponding to the formula C_3H_8O . One of these two species is designated 'normal propyl alcohol,' the other 'isopropyl alcohol.' (This liquid is often used as 'rubbing alcohol.') Everyone agrees that these two types of propyl alcohol are quite different compounds, separate chemical substances. Where species containing only one element are concerned, the word isomer is not used—but if several different elementary substances correspond to the same element they are (as noted above) called 'allotropes.' There are several allotropes of phosphorous (white phosphorous, red phosphorous, etc.). These allotropic forms have quite different properties: they would be recognized by the vast majority of chemists as quite different elementary substances, even though they all contain only one and the same element, phosphorous. A similar situation exists in the case of the element carbon, with several allotropic forms¹³, including graphite and

¹³ In October, 2003, a new allotropic form of carbon that is intermediate between graphite and diamond was reported. (Mao, 2003.)

Running head: Why there is no salt in the sea

diamond—surely quite different materials. Both in the case of the isomers, and for the allotropes of the elements, difference in macroscopic characteristics arise from differences in the ways the atoms are connected together. (The microscopic structure of graphite consists of fairly planar sheets of atoms, while that of diamond is a rigid three-dimensional array.)

How is it that isomers of propyl alcohol and the allotropes of phosphorous and carbon are generally considered different chemical substances while the several phases of water (ice, water, and steam) are recognized as different forms of one chemical substance? The difference on which this distinction in word usage appears to be based is the relative speed of interconversion between the several chemical species. At room temperature, spontaneous transformations of one isomer of propyl alcohol into the other (and the transition from diamond to relatively more stable graphite) are so slow as to be unobservable in practice. Interconversion of the allotropic forms of phosphorous is also quite sluggish (many hours or days), but water, ice, and steam can be interconverted relatively rapidly (a few seconds or minutes). Needham, for his purposes, may quite properly define a clear distinction between the isomers of propyl alcohol and the allotropes of phosphorous but that distinction is not so sharply drawn by practicing chemists.

V

Using salt water (brine) as an example of a solution, Needham concluded that solution properties are not intensive, because solutions consist of parts (salt and water, in this case) that are 'separate' – no part of the salt is part of the water, and conversely. This appears to involve the tacit assumption that neither the salt or the water is changed in any important way by the process of solution. Although this assumption may well be applicable in some cases (such as the formation of an 'ideal solution' by two chemical species that are quite similar to each other—deutero-benzene and benzene, say) it is far from correct for the example that Needham uses, the formation of brine from common salt (sodium chloride) and water, since the components of salt react with the solvent water to generate quite new chemical species (hydrated ions) and all the water is strongly influenced by those reactions.

Running head: Why there is no salt in the sea

than those with 'ideal' behavior (where all changes of properties are linear in the appropriate composition variable, such as concentration of solute).

VI

In what sense does salt exist in brine? To what does the word 'salt' in this question refer? Dictionaries give definitions like:

1 a. Salt (a.k.a. sodium chloride or 'common salt'), a solid material, generally crystalline and white when pure. **1 b.** A salt, a material that resembles common salt, especially in producing an electrically conductive solution with water.

Does the sea *contain* salt? Sea water¹⁵ is an aqueous solution that, on evaporation, yields salt. Colligative property measurements (freezing point depression, etc.) show the presence of *two* solute species in aqueous salt solutions. In aqueous media, salt is *dissociated* into single positive Na(aq.)^+ and Cl(aq.)^- ions. Those undergo weak association reactions to produce ion-pairs, ion triples, etc.. Entropies of solution (Frank, 1957) also show that both types of ions seriously perturb the properties and structure of solvent water. When salt is added to water to produce brine, the solute that is present is not the same as is the ingredient (salt) that was added to the water: also the solvent that contains that solute (to the extent that the solute and solvent can be distinguished) has quite different properties that has pure water. On this basis, neither salt nor water, as such, are *actually* present in sea water.

However, as Aristotle pointed out *On Generation and Corruption* [327^a, 32ff.], in some favorable cases ingredients may be recovered unchanged from combination—so those ingredients may be considered to be present in the combination *potentially*.

What is combination (*mixis*, *mixis*) and what is that which can combine?...[S]ince some things *are potentially*, while others *are actually*, the constituents can be in a sense and yet not-be. The compound may be actually other than the constituents from which it has resulted; nevertheless each of them

¹⁵ Ocean scientists often refer to a certain synthetic solution of fixed composition, known as 'SMOW'— 'standard mean ocean water.'

may still *be potentially* what it was before they combined, and both of them may survive undestroyed....The constituents neither persist actually...; nor are they destroyed, ...for their potentiality is preserved¹⁶. (Emphasis as in the Joachim translation.)

It has been well (and profitably) known for thousands of years that evaporating brine does in fact yield solid salt. Also, water can be recovered by condensing what evaporates from brine. Those undoubted facts do not indicate that salt and water are actually present in brine, any more than a novel is present when a bottle of ink is placed next to a ream of white paper. One can produce salt by placing brine in a shallow pan in a sunny location: one can make a novel by using ink to mark blank paper in appropriate ways. In both cases specific action (admittedly more complex in one case than in the other) is needed to produce the desired product. In neither case does the product, as such, actually exist in the original materials. There is no actual salt in the sea!¹⁷

In common speech, the sea is said to 'contain' salt, the distinction between the two senses of element that Paneth distinguished, and 'matter' and perhaps even 'form' are considered as

¹⁶ The same point was reiterated by Thomas Aquinas: 'The forms of the elements, therefore, are in mixed bodies; not indeed actually, but virtually (by their power). And this is what the Philosopher says in book one of *On Generation*: 'Elements do not remain in a mixed body actually, like a body and its whiteness. Nor are they corrupted, neither both nor either. For, what is preserved is their power.' (Bobik, 2001)

¹⁷ The editor has raised a related (but easier) question: Is there any wheat in 'whole wheat bread'? Wheat grains are certainly ingredients used in making this nutritious product. In that process however, those grains are ground into flour that is then combined with other ingredients (including salt) and baked. Salt can easily be recovered from brine—and even, with some difficulty, possibly from baked bread—but no conceivable process can recover wheat grains from bread. Those grains have been broken down into macromolecular components which have been irreversibly combined (mainly through baking) into new, non-labile, chemical species. Notice that this account is quite different from that of some contemporary Aristotelians (Wallace, 1997) who hold that decomposition to formless 'proto-matter' must occur in substantial change.

Running head: Why there is no salt in the sea

being capable of independent existence. But philosophers are (or should be) quite capable of recognizing the limits of applicability of these common modes of speech.

VII

'Mereology' is a name 'used generally for any formal theory of part-whole and associated concepts' (Simons, 1987) Classic mereology was developed by Stanislaw Leśniewski (1886-1939) partly in order to resolve 'Russell's paradox.' — If a Cretan says 'All Cretans are liars,' should anyone believe him? (Quine, 1980.) A 'mereological whole' is an individual that is composed of parts that are themselves individuals. Any number of individuals of any sort whatsoever (the star Sirius and your left shoe, for instance) can comprise a mereological whole. Both classical mereology and also more recent versions (e.g., Armstrong, 1997) make the assumption that parts are not changed by being associated into wholes.

Simple versions of kinetic theory of gases assume that gas molecules occupy *no* volume and have *no* attractive or repulsive forces between them, and on this basis derive the 'ideal gas law,' $PV = nRT$. Such assumptions are useful, even though they are generally unrealistic, because they provide a reference prediction — what would be expected if, *per impossible*, those assumptions were to hold. The kinds and extent of deviations from the predictions of the ideal gas law that are observed in any specific experimental situation indicate the kinds of extensions and modifications that would need to be made to the simple theory, adequately to deal with that particular case.

Standard philosophical mereology (summarized in an appendix of Needham, 2003) may be regarded as the 'no interaction' theory, analogous to the primitive version of kinetic theory that yields $PV = nRT$. Just as complications need to be added to basic kinetic theory to deal with real gases, so also standard mereology needs to be adjusted to deal with chemical combination (and, perforce, with more complicated interactions).

When solid sea salt dissolves in water to produce brine, both the constituents of the salt and also the solvent water are significantly changed. Parts are modified by their composition into a whole. This situation is excluded, by definition, from standard mereology. Mereology needs to be extended, to apply to cases where the assumption that wholes do not influence parts is not applicable. Chemical systems demonstrate interesting features also seen in more complicated

Running head: Why there is no salt in the sea

problems, but chemical systems can be simplified, described and theoretically discussed much more readily than 'higher level' coherences. (Earley, 2003) Detailed mereological studies of chemical combination should be carried out. Paul Needham has made a strong and valuable beginning in this task (Needham, 2003). He has modified standard mereological practice to include situations where distributed quantities vary in time, and especially significantly, he has developed formal methods to describe situations where several quantities occupy the same location (e.g. a certain volume of solution) at a particular time. This sort of quantity (widely used as both dependent and independent variables) is indispensable for chemists.

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Running head: Why there is no salt in the sea

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Running head: Why there is no salt in the sea

Table 1. Varieties of natural complexes

Consistently interacting ?	Continuant ?	Closed system?	Colligatively constant? (e.g. recrystallizable)	Decomposable?	Stoichiometric?	Several elementary substances, one element?		
Yes. Substances (Millikan)	Yes. Things, Entities, Ousia, (<i>Ousia</i>) Processes	Yes. Chemicals, Stuffs	Yes. Chemical substances	No. Trivially yes. Elementary substances		Yes. Allotropic substances		
				Yes. Compounds	Yes. <i>Daltonides</i>			
			Homogeneous? Yes. Solutions		No, or within ranges. <i>Bertholides</i> Real solutions		Yes. (Nonlinear properties) Non-ideal solutions of allotropes	
				Homogeneous? No Aggregates.			No. Linear properties Ideal solutions	Yes. (Linear) Ideal solutions of allotropes
		No. --- Dissipative structures. (Structures of processes)						Yes. (Inhomogeneous) Allotropic aggregates
		No. ---- Events						
No. ---- Happenings								