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Was Aristotle the Founder of Chemistry?

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Aristotle has recently been construed as the founder of chemistry. Aristotle does give a detailed account of combination in *Generation and Corruption* that can be read as conforming to the kind of combination characteristic of modern chemistry. Nevertheless, to interpret Aristotle's discussion as constituting the beginnings of, or opening the way to, chemistry is to misunderstand both Aristotle and chemistry.

1. Introduction

A recent entry on philosophy of chemistry in the prestigious *Stanford Encyclopaedia of Philosophy* by Weisberg et al. (2011) begins with the following words:

> Chemistry is the study of the structure and transformation of matter. When Aristotle founded the field in the 4th century BCE, his conceptual grasp of the nature of matter was tailored to accommodate a relatively simple range of observable phenomena.

The authors are quite clearly of the opinion that Aristotle founded chemistry in the 4th century BCE, although at the time he was only able to accommodate "a relatively simple range of observable phenomena". One might question the assumption that chemistry is the kind of practice that can be founded by a single individual and what such a founding might consist in. To avoid discussion of that issue I will take the authors to be claiming simply that Aristotle made some significant contribution to the construction of modern chemistry. The treatment of combination by Aristotle in *Generation and Corruption* gives some grounds for this view on the face of it, as we shall see. However, it is argued below that reading that text as constituting the beginnings of modern chemistry involves a misunderstanding of both Aristotle and the nature of that chemistry.

2. Combination as a problem

There is a way of thinking about the kind of chemical combination that became central to chemistry from Lavoisier onwards that makes it puzzling. The puzzling aspect is brought to the fore by pressing the question of whether substances, when combined to

form a compound, persist in the compound. There are grounds for thinking that they do and grounds for denying it. Take, for instance, water, understood as a compound of oxygen and hydrogen. Insofar as the properties of water are to be attributed to the nature of its components it would seem that oxygen and hydrogen must persist in water as its components, bringing about the properties of water through their action. However, we all learnt at school that oxygen relights a glowing splint and hydrogen explodes when brought in contact with a flame. Far from doing either of these things, water extinguishes both a flame and a glowing splint. So how can it be said that oxygen and hydrogen are present in water?

There is a passage in Aristotle's *Generation and Corruption* that can be read as supplying a solution to this very problem. It reads as follows:

> Since, however, some things are-potentially while others are-actually, the constituents combined in a compound 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 may still be-potentially what it was before they were combined, and both of them may survive undestroyed. (For this was the difficulty that emerged in the previous argument: and it is evident that the combining constituents not only coalesce, having formerly existed in separation but also can again be separated out from the compound.) The constituents, therefore, neither (a) *persist actually* — nor (b) are they *destroyed* — for their power of action is preserved. (1, 10, 327b:24–32)[1]

Components exist in a compound insofar as they can be recovered and insofar as they contribute to the properties of the compound through their "power of action". But this existence is only potential as compared to the actual existence of the uncombined components.

I have no quarrel with the idea that a viable notion of combination lies at the heart of the emergence of modern chemistry.[2] However, given the context of this discussion I do not need to argue the case. That is because those with whom I am taking issue, such as the authors of the encyclopedia article cited above, themselves assume combination to be central to chemistry. Their case for the claim that Aristotle made a significant contribution to the advance of chemistry rests precisely on the extent to which he gave a novel analysis of *combination*.

3. Aristotle on combination

The account of combination developed by Aristotle in *Generation and Corruption* should not be interpreted as anything as specific or superficial as the combination of one chemical substance with another to form a compound. Aristotle makes it clear that the first of the two books that comprise *Generation and Corruption* is concerned to address the problem of change in a general and deep sense. The Presocratic philosophers, with

[1] All quotations from Aristotle are taken from McKeon, 1941.

[2] For the historical case for this viewpoint see, for example, Klein, 1994.

whom Aristotle takes issue and attempts to improve upon, were concerned with an ultimate account of change. For them, if A changes into B then there must be a sense in which A differs from B, since there has been a change, but there must also be a sense in which A is the same as B insofar as it is still "it" that has changed. A green leaf turning brown needs to be distinguished from a green leaf being replaced by a brown one. Aristotle's predecessors had assumed that a fundamental account of change capable of countering Parmenides' denial of the possibility of change must involve a persisting reality that survives change. The Presocratics shared the same goal but differed in the accounts they gave of the persisting reality. Aristotle's account of combination was his, distinctive, solution to the problem, which avoided the assumption of a persistent reality underlying all change.

The opening sentences of *Generation and Corruption* (1, 1, 314a:1–) makes it clear that the issue to be addressed is the problem of change *in general*.

> Our next task is to study coming-to-be and passing-away. We are to distinguish the cause, and to state the definitions, of these processes considered in general — as changes predicable uniformly of all the things that come-to-be and pass-away by nature.

The point is reiterated at the beginning of the second chapter where Aristotle signifies that it is unqualified change that is under investigation:

> We have therefore to discuss the whole subject of 'unqualified' coming-to-be and passing-away; we have to enquire whether these changes do or do not occur and, if they do occur, to explain the precise conditions of their occurrence. (1, 2, 315a:26–28)

Another indication that the account of change being considered is, to use Aristotle's term, an "unqualified" account of change rather than superficial one is Aristotle's distinction between the real basis for change and what is revealed of change at the level of perception.

> The opinion, however, that most people tend to prefer, is that the distinction [between substantial change and alteration] depends upon the difference between the 'perceptible' and the 'imperceptible'. Thus, when there is a change into perceptible material people say there is a 'coming-to-be' but when there is a change into invisible material, they call it 'passing away'. For they distinguish what-is and what-is-not by their perceiving and not perceiving, just as what is knowable 'is' and what is unknowable 'is-not' — perception in their view having the force of knowledge. (1, 3, 318b:18–24)

Contrary to popular opinion, perception is a poor guide to the true nature of unqualified change.

> Thus unqualified coming-to-be and passing-away turn out to be different according to popular opinion from what they are in truth. For Wind and Air are in truth more real — more a 'this somewhat' or a 'form' than Earth. But they are less real to perception — which explains why things are commonly said to 'pass-away' without qualification when they change into Wind and Air, and to 'come-to-be' when they change into what is tangible, i.e. into earth. (1. 3. 318b:27–32)

Following his critique of the various accounts of (unqualified) change offered by his predecessors in the first six chapters of Book 1, Aristotle develops his own account in the remaining four chapters of that book, that account being based on his carefully-constructed notion of combination from which the quotation in Section 1 is taken. The novel feature of Aristotle's account of unqualified change is his avoidance of the Presocratic assumption that there must be a reality underlying change that is resistant to all change. It is precisely his account of combination that makes that move possible.

> It is clear, then, from the foregoing account, that 'combination' occurs, what it is, to what it is due, and what kind of thing is 'combinable'. The phenomenon depends upon the fact that some things are such as to be (a) reciprocally susceptible and (b) readily adaptable in shape, i.e. easily divisible. For such things can be 'combined' without it being necessary either that they should have been destroyed or that they should survive absolutely unaltered: and their 'combination' need not be a composition, nor merely 'relative to perception'. On the contrary, anything is 'combinable' which, being readily adaptable in shape, is such as to suffer action and to act; and it is combinable with another thing similarly characterized (for the combinable is relative to the combinable); and 'combination' is unification of the 'combinables' resulting from their alteration. (1, 10, 328b:15–25)

Having given an account of "combination" that is coherent and immune from typical objections in Book I of *Generation and Corruption* Aristotle can now proceed to give the details of his own account of unqualified change in Book II. The opening of that Book makes it evident that this was Aristotle's purpose.

> We have explained under what conditions 'combination', 'contact' and 'action-passion' are attributable to things which undergo natural change. ... But we have still to investigate the so-called 'elements' of bodies.
>
> For the complex substances whose formation and maintenance are due to natural processes all presuppose the perceptible bodies as the condition of their coming-to-be and passing-away: but the philosophers disagree in regard to the matter which underlies these perceptible bodies. (2, 1, 328b:24–34)

Aristotle's account involves the construction of the phenomena of the world by way of the *combination* of the four elements, air, earth fire and water which themselves arise as a result of the *combination* of the hot and the cold and the wet and the dry, the "out of which" the elements are composed. Book II involves the elaboration of the details, which lie beyond the scope of this article.

4. Chemical combination

Modern chemistry does involve the combination of substances to form compounds in a way that conforms to Aristotle's analysis of combination. However, the substances involved are far from being involved in "unqualified" change. The substances that combine and the compounds that result from their combination in chemistry together form a sub-class of substances in general, are accessible to experimental manipulation and have observable or detectable properties that are characteristic of them. The

possibility of *chemical* combination, far from being established philosophically, was an experimental discovery.

There are two key features of chemical combination that have analogues in Aristotle's characterisation of unqualified change. They both concern the way in which components persist in the compounds they form. One feature is the point that components persist insofar as they can be recovered from the compound. Such a feature has become a routine feature of chemistry insofar as it involves analysis and synthesis, building up compound substances from their components and breaking them down into their components. The second feature involves the idea that the properties of compounds are caused by or due to the properties of their components. There are experimentally confirmable correlations between the properties of compounds and their composition. So, for instance, the properties that chlorides have in common are correlated with, or are due to the presence of, chlorine.

The ability to build up substances from, and break them down into experimentally manageable components and to correlate the properties of compounds with their components became possible to a significant degree only in the course of the seventeenth century. A key factor was the increased use of mineral acids. The chemical changes brought about by their use were such that the compounds resulting could be analysed into their components and synthesised from them. This was in contrast to changes brought about by heat and distillation, the procedures that had been the main chemical ones prior to this. The techniques of analysis and synthesis that made the concepts of chemical combination and chemical compound realisable had their origins in the seventeenth and early eighteenth century.

Chemistry, insofar as it involves the analysis and synthesis of compounds, did not exist in Aristotle's day. Just about the only examples of changes known to Aristotle that conform to our characterisation of chemical change involve the formation of alloys, from which the component metals are recoverable. It is significant that Aristotle does not offer an alloy as an example of, or to support, his account of combination. In fact, Aristotle does not give any examples. Insofar as the transformations of substances by burning and distilling can be seen as forerunners of chemical change known to Aristotle, he explicitly dismisses such changes, along with transformation of food by the body, as exhibiting combination.

> We do not speak of the wood as 'combined' with the fire, nor of its burning as a 'combining' either of its particles with one another or of itself with the fire: what we say is that 'the fire is coming-to-be but the wood is passing-away'. Similarly, we speak neither of the food as combining with the body nor of the shape as combining with the wax and thus fashioning the lump. (1, 10, 327b:11–16)

5. Science versus metaphysics

Aristotle's project in *Generation and Corruption* was to respond to Parmenides' denial of change by giving a rational account of it that improved on those of his predecessors. He

offered an "unqualified" account of change that was presumed to underlie all changes in the world, whether observable or unobservable. Characterising specific examples of change, in the domains of meteorology, biology, metallurgy, everyday life or whatever, was not Aristotle's objective in *Generation and Corruption*. (Significantly, I do not list "chemical" as a class of change here since no such category was in use in Aristotle's day.) As we have observed above, observation does not give access to, and gives misleading cues about, the nature of the unqualified change that lies behind it. In modern parlance, the characterisation of unqualified change is *a metaphysical* project and is other than the attempts to characterise the various kinds of change accessible to observation and practical manipulation that, once they reached a significant level of sophistication, became known as science. Weisberg et al. mistakenly identify Aristotle's metaphysical account of unqualified change with the specific, experimentally-accessible account of change that was central to much of chemistry by the time of Lavoisier if not before, being misled by superficial resemblances between the too. They fail to appreciate the difference between metaphysics and science, a hard won distinction that could be appreciated only in the wake of the scientific revolution.

My task is not quite complete. Even if I am right to distinguish between Aristotle's metaphysical account of combination and combination as it became embedded in chemistry, it might still have been the case that the former productively fed into and made possible the latter. It could have been the case that as a matter of historical fact, chemists took hold of Aristotle's account of change and transformed it into a practically realisable form in chemistry. Had this been the case, there could well be grounds for proclaiming Aristotle as the founder of chemistry in spite of the distinctions I have drawn. However, there are no significant grounds for this historical thesis. It is implausible, as well as historically unfounded, to presume that sixteenth century metallurgists and seventeenth century pharmacists who brought about chemical changes that were early instances of, and helped create the preconditions for, a theory of chemical combination were inspired by Aristotle, nor is it plausible that they were concerned with philosophical puzzles underlying chemical combination of the kind that has been our focus. (It is not irrelevant to note that it typically takes a considerable amount of effort to convince a modern chemist that there is something puzzling about chemical combination.) I do not make the detailed historical case here.[3] But it is not as if my opponents make a *historical* case for the influence of Aristotle on modern chemistry either.

Any claim to the effect that Aristotle founded chemistry needs to be based on a characterisation of the relevant writings of Aristotle understood in their historical context, a characterisation of chemistry in its historical contexts and some historical case for a link between the two. I have argued that, once the relevant historical details are attended to, the case for a significant influence by Aristotle on the emergence of a chemistry based on combination evaporates.

[3] Historical studies that help to support my contention are Holmes, 1989; Klein, 1994; Klein, 1996 and Kim, 2003.

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