The Mechanical Philosophy and the Chemical Revolution

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1. Seventeenth–century mechanical philosophy is typically regarded as a critical source for the emergence of modern science.

   - Westfall (1977), *The Construction of Modern Science: Mechanisms and Mechanics*:

     > . . . in the 17th century, the mechanical philosophy defined the framework in which *nearly all creative scientific work* was conducted (p. 41; emphasis added).

   - Shapin (1996), *The Scientific Revolution*:

     > . . . to follow the clock metaphor for nature through the culture of early modern Europe is to trace the main contours of the mechanical philosophy, and therefore of *much of what has been traditionally construed as central to the Scientific Revolution* (p. 32; emphasis added).

2. Will question the view that the mechanical philosophy provided the basis for scientific progress.

3. For some cases, the failure of the mechanical philosophy is well–recognized:

   - Newton's theory of gravitation presented an obvious problem: action–at–a–distance.
     - No one could doubt the predictive power of Newton's theory.
     - Attempts to find a mechanical basis for gravitation continued well into the 18–th century (*e.g.*, Euler).
   - Light as a transverse wave (recognized in the 19–th century) presents a problem.
     - Motion would have to be in a direction orthogonal to that of the impulse.
   - By the 1840s Helmholtz has to redefine the mechanical philosophy to admit any central force!

4. However, focus here will be on chemistry—leading to Lavoisier.

5. Contrast to Fontelle (1699):

   > It is not very long ago that all the reasonings of chemistry were no more than kinds of poetical fictions, . . . gratifying to the imagination, unintelligible, and intolerant to the reason. The sound philosophy has appeared that has undertaken to reduce to simple corpuscular mechanism this chemistry, which was mysterious and in some way so proud of its obscurity.

6. The argument:

   - In the 17–th century, to understand the interaction between the mechanical philosophy and what came to be chemistry, part of the focus must be on Boyle.
   - Hall's (1958) reading of Boyle: the mechanical philosophy was immediately deployed to tackle chemical problems. This led to the formation of chemistry (rather than alchemy).
   - Contrast: a chemical tradition emerged in the 17–th century independent of Boyle (and, arguably, slightly earlier).
   - Even within the alchemical tradition there were explicit shifts to writings that were not intended as esoteric: epxerimental manuals began not to conceals substances and operations—even as early as Libavius' (1597) *Alchymia*.

- This tradition eventually merged with others to become the chemistry of Newton, Stahl, Boerhaave, *etc.* in the 18–th century.
- Central to this tradition was a concept of *element* as well as mixtures/compounds: these were codified into the view that there are intrinsically different types of matter.
- Note the stark contrast to the mechanical philosophy.
- The idea of chemical elements was of central importance in Lavoisier's "new" chemistry; it lies at the core of the so–called chemical revolution.
- Nevertheless, Lavoisier's definition of element was operational/instrumental (see below).
- It remained for Dalton to provide a more "ontological" interpretation of the instrumental (predictive) successes of the new chemistry and associate elements with indivisible unchangeable atoms.
- The mechanical philosophy was peripheral to these developments: indeed, in the 18–th century there was little contact between "natural philosophy" (*i.e.*, physics as we know it) and chemistry.

7. My targets include Metzger (1923) and Hall (1958).

   - These intepretations have been criticized by Golinski (1990).
   - Unlike Golinski, I will maintain a focus on conceptual issues—rather than talk about linguistic and other communicative practice.
   - Will continue to emphasize that teh "philosophy of matter" is central to chemistry.

8. What was the mechanical philosophy?

   - Variant answers depending on whether reliance is on Bacon, Galileo, Descartes, Marsennse, Gassendi, . . .
   - Will use Boyle here (since he is typically included in histories of chemistry).
   - Boyle (1666), *The Origin of Forms and Qualities according to the Corpuscular Philosophy*:

     > That then which I chiefly aime at, is to make it Probable to you by Experiments . . . That allmost all sorts of Qualities, most of which have been by the Schooles either left Unexplicated, or Generally referr'd, to I know not what Incomprehensible Substantiall Formes, *may* be produced Mechanically, I mean by such Corporeall Agents, as do not appear, either to Work otherwise, then by vertue of the Motion, Size, Figure, and Contrivance of their own Parts (which Attributes I call the Mechanicall Affections of Matter, because to Them men willingly Referre the various Operations of Mechanical Engines) or to Produce the new Qualities exhibited by those Bodies, their Action changes, by any other way, then by changing the *Texture*, or *Motion*, or some other Mechanical Affection of the Body wrought upon.

   - From Boyle's theses:

     > I agree with the generality of Philosophers so far, as to allow, that there is one Catholick or Universal Matter common to all Bodies, by which I mean a Substance extended, divisible, and impenetrable.

   - Boyle used "mechanical philosophy" and "corpuscular philosophy" interchangeably.
   - Note that there is no commitment to atomism, *i.e.*, ultimate corpuscles of matter.
   - Also no commitment to whether a vacuum can exist (*contra* Descartes).
   - Boyle's position is fairly standard (contrary to arguments of Garber [2013]).

9. But there are several complications about Boyle:

   - In *Sceptical Chymist* (1661): element defined as "a substance that cannot be decomposed into any simpler substance."

- Appears to contradict that that there is “one Catholick or Universal Matter.”
- Interpretation: Boyle’s chemistry was independent of his mechanical philosophy (Clericuzio 1990).
- Interpretation: There are serious problems with Boyle’s mechanical philosophy (Chalmers 1993).
- There is no doubt that a more complex account of Boyle (than Hall [1958]) is emerging—and we are far from getting a “consensus” picture of Boyle.
- I see a (creative) tension, not a contradiction:
  - Reasonable to interpret decomposition as analysis by heat.
  - Would require more than heat to transmute one element to another.
  - But what is heat? There is tension in Boyle between heat as motion and heat as consisting of a special type of substance.
  - In fact, the caloric theory can be traced back to Boyle (through Boerhaave and others).
  - Note that, if heat is only matter in motion, my resolution of the apparent contradiction will not work.
  - The point that requires most emphasis: Boyle appends the metaphysics of the mechanical philosophy to the operational definition of an element that provides a foundation for chemistry.
  - Lavoiser revives that definition—more than a century later, and this was a critical aspect of the chemical “revolution.”
  - Here, Lavoisier’s work extends that of Stahl and others (Gough 1988): differences about phlogiston were empirically but not conceptually important; the rejection of metaphysical “affinity” was critical.
  - Lavoisier was explicit about rejecting what he called “metaphysical” (as quotations below will show.

10. Early and mid–eighteenth century:
    - The critical (and antagonistic) figures were Stahl and Boerhaave.
    - But behind them always lurks the figure of Newton.
    - Boerhaave is primarily important for his views on “fire.”
      - Boerhaave does not really have a theory of matter—just refers to Newton most of the time.
      - Disappears from the story here.
    - Stahl is the critical figure.
      - Lavoisier’s teacher, Rouelle, was a “Stahlian.” However, Stahl is the direct background against which Lavoisier worked. He rarely refers to Rouelle and, when he does so, it is about minerology rather than geology.
      - Stahl is explicit in rejecting the mechanical philosophy.
      - The critical point is that Stahl insisted on different types of matter.
      - Explicitly, these are *chemically* different.
      - Ambiguity about whether these are also physically different.
        - Stahlians distinguished strongly between physics and chemistry (which was part of the rejection of the mechanical philosophy).
        - By and large, viewed chemistry to provide more fundamental (“intimate”) accounts of matter than physics.
      - Three levels of analysis: element/principle, mixt, and compound.
      - However, Stahl’s views on elements largely followed tradition.
        - Two elements: water and earth.
        - However, there were three different kinds of earth.
        - Fire and air are instruments.
        - Earth and water are also instruments besides being elements.

11. Lavoisier's new system of chemistry.

   - Boyle's definition of element was explicitly accepted by Berthollet, Fourcroy, and Lavoisier in their project of reforming chemical nomenclature from 1782 onwards.
   - The project had three critical aspects:
     - Identification of the elements (Lavoisier published a canonical [corrected] list in *Elements* [1789]).
     - Determine the compounds and name them. The naming was strongly influenced by the successes of Linnaeus in biological nomenclature.
     - Determine how many and which elements went into each compound.
   - This is the highlight of the chemical "revolution."
     - Much of the results (the proportions by which elements combined to form compounds as determined by weights) depended on Lavoisier's long research program on combustion and calcination.
     - Nevertheless, though this also led to the replacement of phlogiston by oxygen, that was not a particularly critical move.
     - The controversy has received unwarranted attention, perhaps thanks to Kuhn (1961).
     - The history does not at all support the claim that there was a *Gestalt* shift in the transition from phlogiston to oxygen which was a slow incremental process in the 1780s.
   - Lavoiser's (1789/1965) remarks on elements:

     > All that can be said upon the number and nature of elements is, in my opinion, confined to difficulties entirely of a metaphysical nature. The subject only furnishes us with indefinite problems, which may be solved in a thousand different ways, not one of which, in all probability, is consistent with nature. I shall therefore only add upon this subject, that if, we apply the terms *elements*, or *principles of bodies*, to express our idea of the last point which analysis is capable of reaching, we must admit, as elements, all the substances into which we are capable, by any means, to reduce bodies by decomposition. Not that we are entitled to affirm, that these substances we consider as simple may not be compounded of two, or even of a greater number of principles; but, since these principles cannot be separated, or rather since we have not hitherto discovered the means of separating them, they act with regard to us as simple substances, and we ought never to suppose them compounded until experiment and observation has proved them so.

   - Note the rejection of metaphysics: hardly surprising that the mechanical philosophy was not important.
   - The book included the first explicit statement of the conservation of matter in chemical reactions.

12. Conclusions:

   - It is hard to see where the mechanical philosophy made a positive contribution.
     - The best bet is the kinetic theory of matter in the 19–th century (and the putative reduction of thermodynamics).
     - However, there are many complications about that reduction.
     - But that is a story for another day.
   - There are thus many interesting questions about the role of reductionism (that wholes must be explained from theri parts) in science since the 17–th century—*e.g.*, whether it has driven research and resulted in progress even as it failed spectacularly.
   - Returning to the chemical "revolution": the relevant question is whether the development of chemistry starting in the 17–th century and, especially, through the 18–th century was *independent* of the mechanical philosophy or in explicit *opposition* to it.

  - Most recent commentators emphasize independence: the non–intersection of "natural philosophy" which is what came to be called physics and chemistry.
  - On this view, a distinct science of chemistry emerged earlier than physics (as understood since the mid–18th century and later.
  - In fact, if there was an opposition to the mechanical philosophy, then there is more conceptual interaction between physics and chemistry in the 18–th century (than if there was indpendence).
  - But that is another story for some other day.

13. Final polemical remarks:

    - The mechanical philosophy was an *a priori* metaphysics: it made strong ontological commitments about the structure of the world.
    - It is thus not surprising that it failed.
    - Contrast to metaphysics as interpreting the implications of physics (or any science).