

Uncorrected proofs. The corrected version published in Davis Baird, Eric Scerri, Lee McIntyre (eds.), *Philosophy of Chemistry: Synthesis of a New Discipline*, in the series *Boston Studies in the Philosophy of Science*, Dordrecht: Springer, 2006, pp. 347-362.

CHAPTER 19

FROM METAPHYSICS TO METACHEMISTRY¹

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THE PROMISE OF METACHEMISTRY

In 1940 appeared *La Philosophie du Non* by Gaston Bachelard. The American edition of 1968 translates the title obviously enough as *The Philosophy of No* and 10 years later, the German followed with *Die Philosophie des Nein*. And yet, *Die Philosophie des Nicht* would have been more appropriate and in English—impossible though it sounds—*Philosophy of Non*. After all, taking his cue from non-Euclidean geometry, Bachelard revels in the “non” of non-Aristotelian logic, non-Cartesian epistemology, non-Baconian science, non-Kantian ontology, non-Newtonian mechanics, and non-Lavoisian chemistry. In all these cases, the “non” does not signal a negation or antithesis but marks Euclidean geometry as a special case of a differentiated non-Euclidean geometry, Lavoisian chemistry as a limited set of practices which is dialectically reflected in non-Lavoisian chemistry, etc. (Bachelard 1968, 55, 115)

According to Bachelard, new experimental procedures and practices of the sciences introduce new ways of identifying, positioning, inferring, or stabilizing events. The sciences thus add over time new layers of conceptualization for properties to “take root” (Bachelard 1968, 45), new spectro-lines to the “epistemological profile” of notions like “mass,” “energy,” or “substance.” Bachelard, therefore, introduces his philosophy of the “non” not as a general theory of science but as an attempt to capture and articulate the significance of an emerging new science that creates in its wake also a new philosophy (cf. Bachelard 1984, 3): Bachelard’s “non” gives “some pre-sentiment of a profound revolution in chemical philosophy.” Signaling this imminent revolution, Bachelard continues, “metachemistry would already seem to be a possibility.”² And: “Metachemistry would be to metaphysics in the same relation as chemistry to physics” (Bachelard 1968, 45). This essay explores Bachelard’s promise of metachemistry. Along the way, it assembles a series of clues that suggest that in the meantime, metachemistry has been more fully articulated or realized in the work of Bruno Latour.³ Though he does not use that term, Latour’s *Pandora’s Hope* (Latour 1999), for example, is a metachemical treatise. However, while Bachelard tries to determine for a new scientific age the relation between metaphysics and metachemistry, Latour offers metachemistry as a way to dissolve

metaphysical pseudo-problems for science in general. This difference calls for an exploration of intellectual contexts. Beginning with the challenge issued by chemist-turned-philosopher Émile Meyerson, this exploration might continue with the response to that challenge by some-time-chemist Gaston Bachelard,⁴ and then perhaps conclude with Bruno Latour's inheritance of Meyerson's and Bachelard's problematics even as he rejects their rationalism.⁵ However, instead of reconstructing contexts and trajectories of influence, the following remarks primarily attempt to get past the idiosyncracies of Bachelard's style—the excess of neologisms, in particular—and clarify his contrast of metaphysics and metachemistry:

Metaphysics could have only one possible notion of substance because the elementary conception of physical phenomena was content to study a geometrical solid characterized by general properties. Metachemistry will benefit by the chemical knowledge of various substantial activities. It will also benefit by the fact that true chemical substances are the products of technique rather than bodies found in reality. This is as much as to show that the real in chemistry is a realization. (1968, 45)

Bachelard's suggestion can be unpacked by highlighting the various stages of this movement from different conceptions of "substance" to the physical, social, as well as conscious "realization of the real." Implicitly and explicitly, the metaphysics and metachemistry of science will be juxtaposed throughout.

THE SUBSTANCE OF "SUBSTANCE"

Metaphysics, Bachelard suggests, operates with an impoverished, insubstantial notion of substance which it inherited—as did classical physics—from the Greek conception of science and its interest in that which persists through change.⁶ "Metaphysics could have only one possible notion of substance because the elementary conception of physical phenomena was content to study a geometrical solid characterized by general properties" (Bachelard 1968, 45).

The general properties of elements are the properties of matter, whether considered as extension and impenetrability or in terms of force or energy. From the spatio-temporal arrangements and re-arrangements of these elements, everything is thought to be composed. This notion of substance is entirely undifferentiated; it does not distinguish anything in particular but characterizes everything material. At the same time, it is generously hypothesized as a pervasive substrate of reality. According to physics and metaphysics, for everything that happens and for far more that could happen, there are latent, immutably lawful general properties waiting to be activated and to manifest themselves. Nature has thus become overpopulated with innumerable dormant powers that are semantically significant yet physically inconsequential.⁷ The varied critiques of metaphysics, therefore, targeted the hypothetical character of substance (though rarely its multiplication beyond necessity), but kept maintaining that all that could be meant by the term "substance" is a persistent constituent of reality.⁸ So, while some critics now claimed that reason or subjectivity is the substance of the world, and while others took the category "substance" in a Kantian

manner as a conceptual pre-condition for the possibility of scientific knowledge, the term kept referring to something self-sufficient and undifferentiated: It is the stuff of the world that persists through change; it is an immutable carrier of accidental properties that is never directly or perceptually cognizable. Since substance is always, perhaps necessarily *hypothesized*, it is attended by the metaphysical question concerning its existence all the way down to the contemporary contest between the “cantankerous twins” of realism (or objectivism) and relativism (Feyerabend 1991, 515).⁹

This *physical* conception of substance was questioned by scientific philosophers like F.W. Schelling, Charles Sanders Peirce, Emile Meyerson, and Alfred North Whitehead.¹⁰ With Bachelard, one might say that their critical questions introduce a *chemical* conception of substance into philosophy. For the chemist, the term “substance” designates first and foremost the particular elementary or compound stuff that stands at the beginning and at the end of a chemical process (cf. Bachelard 1968, 45, 49, 60, 70). As such, chemical substance is no hypothetical substrate but presents itself in chemical practice. Questions regarding its reality concern not its existence but how it makes itself known. Since chemical substance presents itself at different levels of laboratory experience, Bachelard posits a “laminated reality” for chemical substance—“substance does not have, at all levels, the same coherence” (Bachelard 1968, 46):

In the early days of organic chemistry people used to like to believe that synthesis merely served to verify the exactitude of a piece of analysis. Practically the reverse is true now. Chemical substances only get to be truly defined at the moment of their reconstruction. (1968, 47)

As long as synthesis was strictly an analog to analysis, chemistry retained a limited focus on the elementary substrate of particular compounds. At this level, substances are still individualized such that each chemical element might have its own substance (Stengers 1994; Bensaude-Vincent 1994). The coherence of substance increased, however, when synthesis came into its own. The multiple techniques of realization established new chemical relations, suggested functional groupings, allowed for combinations produced in the laboratory to illuminate the combinations found in nature.¹¹ To the extent that this chemical notion of substance became generalized only through the development of converging chemical techniques, the success of the chemist is at odds with the conceptualizations of the (metaphysical) philosopher:

In the face of a reality which has been so surely constructed, let philosophers equate substance, if they will, with that which evades cognition in the process of construction, let them continue, if they will, to define reality as a mass of irrationality.¹² For a chemist who has just realized a synthesis, chemical substance must, on the contrary, be equated with what one knows about it . . . (1968, 47)

This opposition is also present, for example, in Whitehead’s critique of the metaphysical notion of substance, a critique that employs chemical metaphors and ultimately refers to chemistry. According to Whitehead, when we posit that our sense perceptions are merely attributes of a substance, i.e., merely the effects in our minds

of an underlying reality that is already given, “a distinction has been imported into nature which is in truth no distinction at all”:

what is a mere procedure of the mind in the translation of sense-awareness into discursive knowledge has been transmuted into a fundamental character of nature. In this way matter has emerged as being the metaphysical substratum of its properties . . . (1920, 16)¹³

On Whitehead’s account, the “substance” or “substratum” of classical metaphysics results from a process of translation and transmutation, a procedure of the mind that ought to be recognized as such. “If we are to look for substance anywhere,” he concludes, “I should find it in events which are in some sense the ultimate substance of nature” (Whitehead 1920, 19). An example from chemistry helps define what an “event” is: It is “a nexus of actual occasions . . . For example, a molecule is a historic route of actual occasions; and such a route is an ‘event’” (Whitehead 1978, 80).¹⁴

Through a somewhat circuitous historic route of their own, Whitehead’s remarks would leave their mark on Bachelard’s *Philosophy of Non*.¹⁵ Bruno Latour refers to them more explicitly. He, too, shifts from “substance” with all its metaphysical baggage to “event” or “institution.” While this shift applies to all science, it originates in Latour’s discussion of the work of a chemist:¹⁶

What Pasteur made clear . . . is that we slowly move from a series of attributes to a substance. The ferment began as attributes and *ended up being a substance*, a thing with clear limits, with a name, with obduracy, which was more than the sum of its parts. The word ‘substance’ does not designate what ‘remains beneath,’ impervious to history, but what gathers together a multiplicity of agents into a stable and coherent whole. A substance is more like the thread that holds the pearls of a necklace together than the rock bed that remains the same no matter what is built on it . . . substance is a name that designates the *stability* of an assemblage. (1999, 151, *cf.* 167 and 170)¹⁷

Whitehead thus anticipated and Latour echoes Bachelard’s remark, quoted above, “that true chemical substances are the products of technique rather than bodies found in reality” (Bachelard 1968, 45). Now, if events, synthetic reconstructions, and technical realizations are in some sense the ultimate substance of nature, what happened to the original observation that chemical substance is first and foremost the particular, elementary or compound stuff that stands at the beginning and at the end of a chemical process? According to Bachelard, science adds to the “naively” realistic identification of substance (where “substance” is simply predicated) another, “rationalized” layer of meaning (which takes “substance” to be a category of the understanding). While these two layers of meaning exist together in each individual mind and while for each layer substance is what one knows about it, the two layers conjoined do not yield a single coherent notion of “substance.” This is how Bachelard’s conception of laminated or layered reality finally arrives at the third layer of “non-substantialism”: Just as a molecule traverses a historic route of actual occasions, so does the notion of ‘substance’ itself. And since that route itself is the event and since the event is in some sense the ultimate substance of nature, Bachelard finds that the ultimate substance of ‘substance’ has dissolved into its own history of rationalizations and conceptualizations (1968, 44, 72f., 76).¹⁸

LAVOISIAN SCIENCE

Bachelard's construction extrapolates not only from the history of philosophy but also, more significantly, from that of chemistry. According to Bachelard and Meyerson before him, the development of chemistry itself offers a philosophical history of "substance." Like Meyerson, Bachelard believed that only with Lavoisier "(t)he scientific mind has . . . completely supplanted the pre-scientific mind" (Bachelard 1968, 47f.). According to Meyerson, "science in its entirety" takes place in the interval between on the one hand perceived, sensible every-day reality which science destroys, and on the other hand the eventual "disappearance of matter (or the dissolution of substance) into the ether" which concludes the project of science (Meyerson 1991, 407). While "the claims of phlogiston theorists were also based on observation" (Meyerson 1991, 207), they did not employ the principle of conservation consistently, did not use that principle to destroy sensible reality, did not "impoverish reality to create legalistic science" (Meyerson 1991, 407), and they, therefore, spoke of chemical change in qualitative terms as if properties passed from one body to another (Meyerson 1991, 206f.). Lavoisier employed a principle of conservation to institute a legalistic science which then creates "theoretical science by stripping reality as much as possible of any qualitative elements" (Meyerson 1991, 407), substituting the motion of invisible entities for the passage of sensible properties (Meyerson 1991, 206f., cf. 62ff.).¹⁹ "In a certain sense," Meyerson adds, the quantitative beings of theoretical science are "even more substantial" than "the things we believe we perceive": "They are assumed to be actual substances, and science, by taking away their qualitative aspect . . . added to their perdurability" (Meyerson 1991, 407). Thus, the essential form of our science appears to us to be shaped above all by the concern to explain that which changes by that which persists (Meyerson 1991, 130, cf. 119).

On Meyerson's interpretation, then, Lavoisier took an important step toward the fulfillment or realization of the Greek program in philosophy and science: He dissolves time into space and shows that qualitative change is not real while the underlying invisible elements are all the more real as they persist through mere displacements or changes of location.²⁰ Meyerson thus takes the Lavoisian shift from one conception of substance to another as instituting just that idealized conception of science which Meyerson embraces. While Meyerson is explicitly committed to a metaphysical conception of science, his historical account yields an implicitly metachemical claim. Indifferent to the problem of existence and the ultimate foundation of reality, metachemistry concerns the processes by which reality is transformed. According to Meyerson, Lavoisian science is guided by a physical ideal and thereby transforms reality by dissolving matter into ether, time into space, that which is perceived into that which is inferred and, of course, chemical substance into physical substance. Meyerson's implicit metachemistry came into its own when the further development of chemistry revealed that the "Lavoisian" ideal is just that—a particular metachemical stance among others, compelling but limited. According to Bachelard, these limitations became apparent and an explicit metachemistry became a possibility, once certain tensions within the Lavoisian conception of science and substance became productive and served to differentiate Lavoisier's substantialism or—in Bachelard's terminology—once they "dialectized" it.²¹

As with all dialectical movements, the development of alternative or differentiated metachemical stances and of non-Lavoisian science accentuates ambiguities that were already present in Meyerson's conception of science as well as in Lavoisier's conception of chemical substance.²² On the one hand, as described by Meyerson, Lavoisier physicalizes chemical substance by ruling that "in all the operations of art and nature, nothing is created." On the other hand, as Bachelard points out, Lavoisier's scientific practice and his definition of "element" establish that as the products of technique, substances are realized.²³

Realizations have to be multiplied. One has more chance of knowing sugar by making sugars than by analyzing a particular sugar. In this plan of realizations, one is not looking for a generalization anyway, one is looking for a *systematization*, a *plan*. The scientific mind has *then* completely supplanted the pre-scientific mind. To *our* way of thinking, then (as opposed to Meyerson's), *this* is reverse realism . . . *It* is the foundation of chemical rationalism. (1968, 47f.; emphases added)

Bachelard's remark articulates tensions within Lavoisian science: The creative work of scientists in Lavoisier's laboratory is supposed to establish that nothing is created and everything merely discovered. The nature of "sugar" arises from the making of "sugars," and the substance in the singular appears not as an immediate likeness among the plurality of particulars but as a co-ordination of practices. The presumed nature informs research only as a category of possible experience for the representation of "sugar." Instead of generalizing from the experience of an unchanging reality, the systematic course of inquiry and the plans of science carve out an unchanging reality. This is "reverse realism" in that reality appears not as the cause of perception but as the product of inquiry.²⁴ And while Meyerson celebrates the intended product of Lavoisier's science, Bachelard emphasizes its procedure. According to Bachelard, it is this tension between intended representation and the making of it which gives rise (within the rationalized substantialism of Lavoisian science) to the non-substantialism of a non-Lavoisian science that reflects this tension in its practice.

NON-LAVOISIAN SCIENCE

Bachelard only hints at this non-Lavoisian practice, and these hints can be patched together in a tentative manner at best.²⁵ The most prominent among them strikes right at the heart of Lavoisian science with its reliance on principles of conservation:

As there are geometries which do not obey the displacement group, which are organized around other invariants, it is to be foreseen that there are chemistries which do not obey the conservation of matter²⁶ and which could, therefore, be organized around some invariant other than that of mass. (1968, 54)

Bachelard says little about what these invariants might be, whether one of them will replace "mass" or whether non-Lavoisian science varies the invariants in order to gain a multi-perspectival, properly dispersed access to the layers of reality. The latter

possibility may be implicit in his suggestion of an alternative to Meyerson's Lavoisian ideal:

it was believed that structural conditions decided everything, the idea being, no doubt, that one masters time when one is well organized in space, with the result that all temporal aspects of chemical phenomena came to be neglected. There was no appreciation of the fact that time was itself structured; no pains were taken to study rates, unfoldings, operations, transformations—along these lines, therefore, there is new knowledge to be gained. (1968, 72)

Depending on the level of organization or experimental intervention at which these transformations are studied, the new knowledge to be gained will differentiate the notion of substance. Bachelard suggests that in metachemical substance converge three separate notions, one of which is the traditional metaphysical conception of “substance.” It is complemented by “sur-stance” and “ex-stance” (Bachelard 1968, 66). “Sub-stance” refers to what stands behind, beneath, or before the observed phenomena; “sur-stance” refers to what emerges in the process of realization, namely what Latour calls an institution which co-ordinates human and non-human practices.²⁷ “Ex-stance” finally refers to the excess of meaning that is not absorbed within a single coherent notion of substance and that tends to be overlooked by Latour.²⁸

Metachemistry would thus “*disperse* substantialism,” where the metaphor of dispersion is borrowed from spectrographic analysis (Bachelard 1968, 45). Extending this spectroscopic analogy, Bachelard represents the differentiation of “substance” by means of a chemical and not at all Freudian “psycho-analysis.” The spectrographic dispersion of substantialism produces spectro-lines of “substance” where the ensemble of the lines provides the psycho-analysis of the mental construction of that concept. What Bachelard calls the epistemological profile of “substance” is of the same time a representation of its laminated reality, namely the successive layers of naive realism with its predicative use of “substance,” of rationalism or Kantianism in which substance is a category, of its “dynamization” in terms of sub-stance, sur-stance, ex-stance. The resultant profile would be similar to the one he produced for his personal notion of “mass” (Figure 1). Since “(p)hotochemistry, with the spectroscope, seems

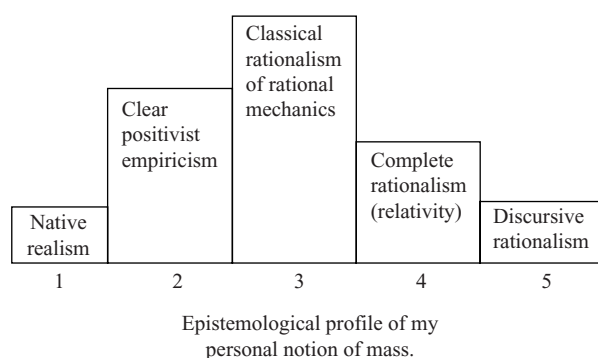


Figure 1: Bachelard's spectroscopic “psycho-analysis” of mass (Bachelard 1968, 36).

to be a non-Lavoisian chemistry” (Bachelard 1968, 58), Bachelard here draws in a self-exemplifying manner on a non-Lavoisian technique to advance his argument for a non-Lavoisian metachemistry.

THE CHEMICAL TRAJECTORY OF PHYSICAL REALIZATION

As opposed to metaphysics, metachemistry does not attempt to decide between naive realism and the various shades of rationalism; instead, it produces dispersion analyses of notions like substance or mass, fire or air, at various stages on their route toward the realization of the real. It is this route and the development of propositions over time that finally needs to be elucidated.

“(W)here shall we find the facts that foreshadow, as we have come to believe, the non-Lavoisian aspect of generalized chemistry?” Bachelard asks and immediately provides an answer: “They are to be found in the *dynamization* of chemical substance” (Bachelard 1968, 55). He then begins to elaborate this dynamic and temporal, if not historical character of chemical substance:

(T)he reaction must henceforward be represented as describing a course, as forming a chain of various substantial states, or a movie film of substances . . . Immediately a *becoming* defines itself underneath being. Now this becoming is neither unitary nor continuous. It presents itself as a sort of dialogue between matter and energy . . . Energy is as *real* as substance and substance it *not more real* than energy. Through the intermediary of energy time puts its mark on substance. The former conception of a substance by definition, outside of time, cannot be maintained. (1968, 56f.)

The former conception of substance rendered it a hypothetical entity precisely because it was posited as that which persists through time. Even among those who agreed that the world is intelligible to the human mind only if the persistence of substantial characteristics is assumed, the gulf between realists and anti-realists opened up: With Whitehead, Locke, and most Kantians, anti-realists suspect that realists are transmuting a posit of the mind into a fundamental character of nature (see the discussion of Whitehead in the section on “The Substance of ‘Substance’” earlier). However, as soon as one lets “time put its mark on substance,” the hypothetical character of persistence drops out, and the old debate of realists versus anti-realists becomes obsolete. It is replaced by the question of how substance is instituted and how its reality becomes physically, socially, consciously realized over the course of time.

Whitehead referred the institution of “substance” to the nexus of actual occasions or operations, i.e., to an intrinsically historical event. Bachelard goes on to pursue “the dynamization of substance” and considers its history as a *series* of events by adopting Paul Renaud’s metaphor of a “chemical trajectory” (Bachelard 1968, 61) that can be represented as a continuous line or curve:

It is quite natural to say . . . that the substance being purified *passes through* successive states, and it is no far cry from here to the supposition that purification is *continuous*. If one hesitates to postulate this continuity, at least it is not difficult to accept . . . that the purification can be *represented* by a continuous line. (1968, 61)

This continuous line represents the “incorporation, within the definition of substances, of the conditions needed to detect them” (Bachelard 1968, 59). In other words, “when one of the variables included in the representation is *time* and the other variable corresponds to some characteristic of substance,” a chemical trajectory becomes visible (Bachelard 1968, 64).

What Bachelard is suggesting here is that one might graph the definition or institution of substance. This graph would represent a route or passage of purification. The choice of variables avoids the metaphysical pre-supposition that there is a stable “it” that is being purified. The apparent constancy of this “it” emerges only from the actually observed persistence of the characteristics over time, i.e., only from the tentative continuity of the line. In this sense, the “representation” provided by the graph is not a representation *of* reality but expresses the “*supremacy of representation over reality*” (Bachelard 1968, 62):

The representation of the purifying passage vouchsafes that there is a continuous “it” there.²⁹ Substances thus emerge from the acquisition of more and more characteristics: They become more articulate and better articulated as they incorporate “more and more of the conditions needed to detect them.” (1968, 59)

In other words, substances become increasingly reliable or stable actors in experimental and technological interactions, i.e., as the situations are defined and become defined in which they will assert themselves in certain ways.³⁰ The trajectory is, therefore, graphed in reference to two variables: The time that passes as the work of science goes on, and a scale that registers the increasing specificity of the characteristics with which the substance becomes identified.

In the course of his own metachemical investigations, Bruno Latour produced Bachelard’s graph. It represents not the discovery of Tasmania but its “construction” through the collaboration of navigators, explorers, ships, currents, coasts, map-makers, etc. (Figure 2).

Over time and through the collective work of scientists, some vague “it out there” acquires more and more characteristics, more and more associations, becomes

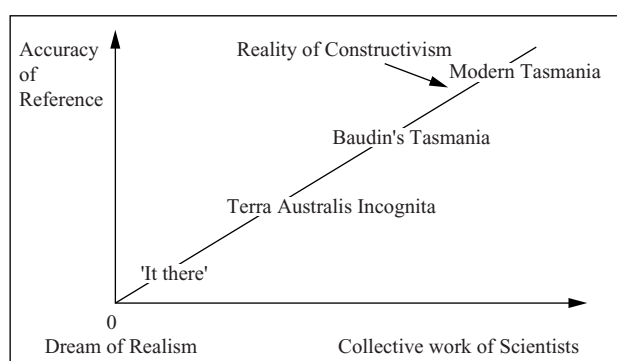


Figure 2: The realization (“discovery”, exploration, mapping, etc.) of Tasmania (Latour 1990, 68).

institutionalized at the nexus of numerous occasions until it becomes “modern tasmania” to which we now refer with great accuracy.³¹ Latour’s graph attempts to capture also how the gulf between realism and anti-realism is bridged by this representation of substance as vouchsafed by a “historic route of actual occasions” (Whitehead 1978, 80).

The “dream of realism” views the trajectory prospectively as the unfolding of a given substantial reality. Metaphysical realists would claim that Tasmania always was what it is, that it was merely discovered and has not substantially changed from the time when it was completely unknown and void of any specified characteristics, to today when it is articulated in great detail. Latour and the metachemistry of science consider a peculiar obsession this attempt to insist that “modern tasmania” is identical to the eternal timeless substance that, on the dream of realism, must have been there all along.³² One can understand this obsession if one understands that for the metaphysician, the timelessness of substances serves as the foundation of the real and that, therefore, the denial of this identity would cast us into the abyss of relativism and deprive us of all reality (cf. Latour 1999, 3–9, 296).

The “reality of constructivism,” on the other hand, views the graph’s point of origin as a fictitious common referent, the vague “it out there” to which characteristics gradually accrue and are imputed retroactively. The trajectory itself, i.e., the history of “Tasmania” links the dream of realism (world) and the reality of constructivism (language). Instead of pitting realism against constructivism, Latour argues that the dream of a stable reality is realized as stability is forged, and one of the characters that “Tasmania” acquires in the course of its interactions with navigators, map-makers, inhabitants is the character of obduracy or persistence.³³ If things, objects, substances, and facts have histories, they may well have been different in the past and did not yet have certain defined traits before humans encountered them. However, Tasmania proved itself to be so steady and reliable that we readily extrapolate its existence into the future and the past, claiming by a kind of inductive argument that it possessed its most stable characteristics even before they acquired the character of stability-in-interactions.³⁴ The metachemist Latour thus agrees with Whitehead, Bachelard, and—philosophically more radical and sophisticated than either of them—Charles Sanders Peirce. They all view reality as standing at the end of inquiry or appearing in its course.

METAPHYSICAL PHILOSOPHY, METACHEMICAL HISTORY OF SCIENCE

If metachemistry stands to metaphysics as chemistry to physics, what then is their relation? The answer to this question refers us to the thorny issue of whether physics is somehow fundamental or prior to chemistry—a loaded question in that the very notions of the “fundamental” and the “prior” have “metaphysics” and not metachemistry inscribed in them. Here is a tentative sketch of the relationship: Bachelard and Meyerson agree (but Latour tends to overlook³⁵) that metaphysics posits the scientific picture of the world, i.e., conditions of intelligibility. Metaphysics is, in that sense, conceptually prior and ulterior; it formulates (as Meyerson emphasized most

explicitly) an idealized anticipation of what science intends. In the language of Peirce, one should say that metaphysics introduces the hypothesis of reality. How must we conceive world and nature if we want to arrive at or realize a stable and representable reality? And in Kantian terms, one might say that metaphysics specifies the conditions for the possibility of objective knowledge. The world it posits is all that is the case, i.e., the static world of Wittgenstein's *Tractatus* which is composed of discrete states of affairs and which is amenable to representation. The modern science of chemistry also intends such a world, and (meta)physics has, therefore, come into chemistry by way of conservation principles, by way of the periodic table and its interpretation in terms of substantial atoms or in terms of molecules and an insubstantial plurality of elements. It also comes into chemistry by way of quantum mechanics and its attendant tools of analysis.³⁶

In contrast, metachemistry informs and traces the practice of science. Moving alongside science, it characterizes the stuff of science, namely the operations in the heads and laboratories of scientists: What kinds of transformation produce a durable representation of the world that can be fixed in thought as a world of representation? Any theory of inquiry, therefore, must treat objects and substances, instruments and propositions, models and theories, nature and culture, mind and matter metachemically on their historical trajectories. In the language of Peirce, one should say that metachemistry develops the hypothesis of reality: How do humans and nature interact in the fixation of belief and reality?³⁷ If there were Kantian terms available here, they would concern the conditions for the synthesis of apperception. The later Wittgenstein, at any rate, considered metachemistry by trying to relate sentences like "all is flux" to the static world of the *Tractatus*. To the extent that chemistry is still a science of becoming (Earley 1981; Müller 1994) and to the extent that all sciences are engaged in the realization of the real, metachemistry extends from the practice of chemistry into the laboratories of physics.

The priority of (meta)physics, therefore, consists in the scientifically intended image of an objectively knowable world, the final and formal causes of scientific inquiry. The priority of (meta)chemistry, on the other hand, consists in the synthetic making of this stable world of representation, the material, and efficient causes of scientific inquiry.

NOTES

1. Small papers with grand titles are bound to be programmatic. This one is no exception and, along with Nordmann (2000), marks only the beginning of what should become an extended course of inquiry.
2. I am here following the French original: "Dès maintenant, une métachimie nous paraît possible . . . La métachimie serait à la métaphysique dans le même rapport que chimie à la physique" (Bachelard 1981, 53).
3. See Latour (1999, 142–144) on the relation between articulation and realization (a relation emphasized already by Charles Sanders Peirce). A metachemical stance has also been suggested in the later work of Feyerabend (1991, 507–521).
4. He taught physics and chemistry from 1919 to 1930 at the Collège Bar-sur-Aube; one of his two dissertations of 1927 concerned thermal propagation in solids; and in 1932 he published *Le Pluralisme Coherent de la Chimie Moderne*. On Bachelard's philosophy of science see Tiles 1984.

5. While Bachelard rejects Meyerson's conservative or Lavoisian ontology of timeless identities rather than historicized substances, he shares with Meyerson the conviction that science rationalizes nature. Latour completes the critique of Meyerson when he rejects Bachelard's rationalism and criticizes his view that epistemological breaks objectify science by displacing intuitive and mythologically "realistic" views (Latour 1995, 81 and 124ff.).
6. Aside from some of the following quotes, see Ted Benfey's opening remarks at the 1999 International Conference on the Philosophy of Chemistry.
7. Bachelard describes how "each simple substance actually received a substructure. And the characteristic thing was that this substructure revealed itself as having a totally different essence from the essence of the phenomenon being studied. In explaining the chemical nature of an element by an organization of electric particles [...] [a] sort of non-chemistry constituted itself to sustain chemistry" (Bachelard 1968, 52).
8. This can be seen, for example, in two historical dictionaries of philosophy that represent the state of philosophical discussion at the time when Whitehead enters the scene with Bachelard following soon thereafter. See the entries on "Substanz" in Michaëlis (1907, 607–610) and in Eisler (1904, vol. 2, 450–464).
9. These are "cantankerous twins" because they arose together along with the metaphysical conception of substance. According to Bachelard, for the metaphysical realist "*existence is a one-toned function*," that is, everything is real or unreal in the same way, in that it either exists or does not exist—"the electron, the nucleus, the atom, the molecule, the colloidal particle, the mineral, the planet, the star, the nebula" (Bachelard 1968, 46).
10. Indeed, the physical concept of substance was questioned implicitly also by the development of the sciences throughout the long 19th century (1780–1920), by the development of modern chemistry, statistical mechanics, Darwinism, electrodynamics, relativity and quantum theory. According to Wilhelm Ostwald, therefore, the notion of "substance" merely sets the task for scientists to determine what does and what does not possess the property of conservation or persistence (cf. Eisler 1904, vol. 2, 464). It would be a worthwhile project to see just how far back into the 19th century can be traced the notion that the chemical notion of substance is so deeply at odds with the physical one as to require a re-orientation of philosophy. As early as 1863, for example, Ernst Mach criticizes the mechanical conception of substance by suggesting its inapplicability to chemistry. One should not "imagine the chemical elements lying side by side in a space of three dimensions" or else "a crowd of the relations of the elements can escape us" (Mach 1911, 53, see 43, 54, and 86ff.). Lange quotes Mach in his *History of Materialism* (Lange 1925, 388). According to Bertrand Russell's 1925-preface to the English edition, Lange's own work contributed to the critique of substance, a concept that "persisted in the practice of physics" until the arrival of relativity theory. At the present time, according to Russell, physics can finally agree that "[n]othing is permanent, nothing endures; the prejudice that the real is the persistent must be abandoned" (Lange 1925, xii).
11. Bachelard quotes a particular example concerning the chains of groups of CH₂ from Mathieu (1936, vol. 1, p. 9).
12. Bachelard's strong claim that metaphysicians "define reality as a mass of irrationality" is echoed and perhaps clarified by Bruno Latour. According to the latter, the metaphysical conception of substance recommends itself on first sight because it gives "a clear meaning to the truth-value of a statement": Scientific statements can be said to refer if and only if substantial states of affairs correspond to it (for the tight connection between physical substantialism and the representability of states of affairs, see Wittgenstein's *Tractatus* 2.0211). With the notion of reference, however, arises the problem of how to bridge the gap between language and world: "In spite of the thousands of books, philosophers of language have thrown into the abyss separating language and world, the gap shows no sign of being filled [...] except that now we have an incredibly sophisticated version of what happens at one pole—language, mind, brain, and now even society—and a totally impoverished version of what happens at the other, that is, *nothing*" (Latour 1999, 148).
13. "The history of the doctrine of matter has yet to be written. It is the history of Greek philosophy of science. [...] The entity has been separated from the factor that is the terminus of sense awareness. It has become the substratum for that factor, and the factor has been degraded into an attribute of

the entity. In this way, a distinction has been imported into nature that is in truth no distinction at all” (Whitehead 1920, 16). Elsewhere, Whitehead characterizes this transmutation as the fallacy of misplaced concreteness. According to Bachelard, Kantianism moved from naive realism and traditional metaphysics to a critical rationalism that considers “substance” a category of the understanding (see Kant’s *Critique of Pure Reason*, note on B xxi). Whitehead’s critical question places him between Kantianism and Bachelard’s third stage of chemical philosophy (Bachelard 1968, 45, 50ff.).

14. Joseph Earley (1981) amplifies this chemical dimension of the “event.” Whitehead qualifies the “nexus of actual occasions” in a manner that threatens to sneak the abandoned metaphysics back in: The nexus is “inter-related in some determinate fashion in some extensive quantum” (1980, 80). Quite in the spirit of Bachelard’s “philosophy of ‘non’,” however, Whitehead’s non-metaphysical and metachemical conception of substance appears to *explain* metaphysics in metachemical terms, namely as a transmutation (as, for example, through misplaced concreteness).
15. Bachelard (1968, 66) refers for inspiration to a remark “Sur Whitehead” by Jean Wahl: “La réflexion sur Whitehead me fournit aujourd’hui un nouvel élément: à l’idée de substance pourrait-on substituer l’idée de sur-stance? (idée qu’un ensemble organique est quelque chose de supérieur à ses éléments). On retrouverait l’entéléchie aristotélicienne, la ‘vérité’ hégélienne, l’émergence d’Alexander” (Wahl 1938, 931). A philosophical history of metachemistry would, therefore, have to consider wider contexts such as French existentialism.
16. Latour may have been introduced to Whitehead through Isabelle Stengers, cf. Latour (1996, 1999) and Prigogine and Stengers (1984).
17. Latour’s mixing of metaphors indicates just how difficult it is even for him to get away from appeals to prior substances. For Latour’s “search for a figure of speech,” see Latour (1999, 133–144).
18. Latour details this process in a chapter on “The Historicity of Things: Where Were Microbes Before Pasteur?” (Latour 1999, especially 164–172; see also Latour 2000).
19. Compare Bernadette Bensaude-Vincent’s characterization of Lavoisier’s achievement: “In the act of weighing, Lavoisier sought to create an experimental space that was entirely under the experimenter’s control. Once balanced with weights on Lavoisier’s scale, substances were transformed from objects of nature to objects of science. The balance divested substances of their natural history. Their geographical and geological origins, their circumstances of production made little difference. They were transformed into samples of matter made commensurable by a system of standardized weights. [. . .] In translating the conservation of elements’ qualities into quantitative and ponderal terms, the principle dodges the question how—in what form—the elements are conserved. How do they subsist in compounds and how do they move from one compound to another during a reaction?” (Bensaude-Vincent 1992, 222ff.)
20. According to Meyerson, Carnot’s principle concerning the irreversibility of time is factually true but irrational in that rational science follows the principle of causality that pre-supposes reversibility and the identity of antecedent and consequent; science thus “tends to the elimination of time.” Carnot’s principle asserts reality as it resists, from without, our scientific attempts at rationalizing it (cf. Meyerson 1930, 278, 286, 317). According to Meyerson, Carnot’s principle signifies a limit of science.
21. However, cf. Bachelard’s remark that “a metachemistry came into being with the Mendeleef table” which appears to be at odds with the sustained emphasis on metachemistry as part of a new scientific spirit (Bachelard 1968, 49).
22. “It is to be understood—we cannot stress this often enough—that a non-Lavoisian chemistry, like all the activities of the philosophy of non, does not deny the utility of classical chemistry, either for the past or for the future. It tends merely toward the organization of a more general chemistry, a pan-chemistry, just as pan-geometry tends to give the plan for the possibilities of geometrical organization” (Bachelard 1968, 55).
23. Latour refers to Bachelard’s “un fait est fait” when he embarks upon his own project to show how it can be that facts are at the same time “fabricated” and “real” (Latour 1999, 127), how the statement “the ferment has been fabricated in my laboratory” can be understood as synonymous with “the ferment is autonomous from my fabrication” (Latour 1999, 135).
24. According to Peirce, this “reverse” or Kantian realism is just realism plain and simple as opposed to nominalism that posits reality as prior to inquiry. Peirce articulates this in some of his earliest papers in Peirce (1992). Peirce reflects the tension between Meyerson’s explicitly metaphysical stance with its

- “nominalist” conception of a substantial and persistent reality and his implicitly metachemical account with its “realist” conception of science as effecting transformations and creatively producing reality in the metaphysical or nominalist image.
25. A more complete account might be reconstructible if one considered Bachelard (1932), the work of Georges Matisse who appears to have coined the term “non-Lavoisian” (Matisse 1938), perhaps Paul Renaud’s *Structure de la Pensée et Définitions Expérimentales* (1934) or the influence on Bachelard of Leo Brunschvicg (1937).
 26. The English edition accidentally prints “water” instead of “matter,” but see Bachelard (1981, 64).
 27. See note 15 above for the “emergence” of “sur-stance” (in the sense of an Aristotelian or Hegelian entelechy) and on how it was inspired by Wahl and Whitehead.
 28. See notes 31 and 35 below.
 29. To Bachelard’s interest in “representation” (Bachelard 1968, 62–64) corresponds Latour’s appropriation of Whitehead’s “proposition” (Latour 1999, 141, 148): Both terms elude the misleadingly dichotomized spheres of noumenon and phenomenon (Bachelard), of subject and object (Latour).
 30. The preceding sentences have begun to conflate Bachelard’s and Latour’s vocabularies.
 31. While the construction and maintenance of a fact requires an unbroken trajectory, why should the trajectory also be straight? Jeff Ramsey raises this point (cf. Ramsey 1992): Does Latour’s anti-mentalism commit him to the view of an ineluctable conspiracy of associations that tends to agreement, stability, accrual of properties? If ideas or “epistemological breaks” play any rôle at all, can they do anything but introduce instability, open black boxes, unravel an accomplished reality? Substituting railway tracks for trajectories, an alternative approach is suggested by Max Weber: “Interests (material and ideal), not: ideas, immediately govern the actions of people. However, the worldviews that have been created by these ideas have often determined, like switchmen, the tracks along which action is propelled by the dynamics of interest” (Weber 1920, 252). The notion of ideas providing *direction* and altering the course of events is consistent with Latour’s (and Peirce’s) emphasis on continuity and the *unbroken* chain of operations: “To scientific facts pertains as to frozen fish that the chain of coldness which keeps them fresh may not be interrupted, not even for a moment” (Latour 1995, 159). Thus, while the trajectory has to be unbroken, there is no need for it to be straight, and indeed it ambulates in Latour’s more recent graphs (Latour 2000, 256).
 32. Latour’s critique of this obsession is discussed in Nordmann (2000). His critique exemplifies another dimension of his literally non-Lavoisian commitments, namely his view that experimentation should not be considered a zero-sum-game in which nothing is gained or lost.
 33. Compare Bachelard (1968, 13): “Chemical substance will come to be represented as a part—a mere part—of a process of differentiating; the real will come to be represented as a moment of realization well carried out.”
 34. “A little history spawns relativism,” writes Latour, “a great deal engenders realism” (Latour 1996, 91). If we historicize our ways of knowing only, we remain bound to metaphysics and open an abyss between eternal truth and constructed knowledge; if, however, we historicize the production as well as the objects of knowledge, a Peircean realism becomes possible. Peirce and Latour detail this possibility, both attempting to explain how the objects become known or determined in such a way that their acquired specifications appear timeless. What the object acquires over time is substance; in other words, it takes on a nature, and thus a substance can *become* something that it has *always been*. These proposals obviously require greater critical scrutiny; the brief account provided here is far too sketchy. Cf. note 24 above, Latour (1999, 145–173).
 35. Perhaps, I should say “as Latour must overlook” since he sets to out to provide without reference to mental entities (ideas, beliefs) a symmetrical “anthropology” that can *explain* the world as it is today; that is, it can explain what is and *through what activity it has become differentiated*. In contrast, the metaphysical stance *reflects* on our *representations* of the world. Once one considers thinking a powerful, consequential, and continuous human activity that occasionally produces representations, one can appreciate the relation between Latour’s dynamically continuous metachemistry and a statically reflective metaphysics.
 36. Bernadette Bensaude-Vincent has detailed the struggles and trade-offs that came with this fashioning of chemistry after a metaphysical image of science.

37. Physics and metaphysics articulate a timeless, perhaps quantitative ontological framework, chemistry and metachemistry study genuine qualitative change, that is, processes that cannot be represented as displacements of material points. The picture I am invoking here of the relation between (meta)physics and (meta)chemistry has all the hallmarks of late 19th-century scientific philosophy. It is questionable, of course, whether this picture has survived the 20th century.

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