New Tools for Philosophy of Chemistry

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Abstract: Three concepts have recently been added to the resources of the philosophy of chemistry – 'affordance' from J.J. Gibson's (1967) perception studies, 'hinge' from Ludwig Wittgenstein's later philosophy (Wittgenstein 1974), and the 'mereological fallacies' from the critical discussion of neuropsychology by M.R. Bennett and P.M.S. Hacker (2003). Together they have to some extent opened the way for a reshaping of the materialist metaphysics of chemistry. When made use of in the philosophy of chemistry they also represent a renewed emphasis on chemical practice and its relation to the products of chemical activity. In addition to that shift of emphasis, the analytical use of the three concepts reveals the extent to which the environment of chemical processes is an essential component in chemical explanations. The analytical tool kit is completed by the revival of the model centered approach to the understanding of how the content of theories is established, changes, and grows. The fourth concept, that of the 'iconic model' (Hesse 1963), completes the equipment needed to examine the intelligibility of chemical discourse and practice in more detail than heretofore.

Keywords: *affordance, hinge, model, mereological fallacy, J.J. Gibson, Ludwig Wittgenstein*.

1. Introduction

In this brief study I want to show how the four conceptual tools, 'affordance', 'hinge', 'model' and 'mereological fallacy' fit together into a coherent approach, a kind of working 'meta-chemistry' with which the conceptual content of chemical discourses can be extracted and examined. Taken together they serve as a tool kit with which to approach some of the philosophical problems that have emerged in the philosophy of chemistry in the last four hundred years. Philosophy of chemistry is an analytical project aimed at bringing to light the facets of chemistry that support our confidence in the rationality of its practices and the intelligibility and coherence of its concepts. Elementary chemistry that we learn at school describes reactions that occur in a featureless domain, a bland and stable environment. Everything almost

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without exception happens at normal temperature and pressure and at normal time scales. We can transfer the formulae of elementary chemistry to other times and places and they will provide a reliable guide to what reactions we should expect provided the alternative environments are not too extreme. This is a background assumption that affects even the most sophisticated chemical thinking of the past, for example Mellor's once famous textbook much used in the early parts of the 20th century (Mellor 1914). In contemporary textbooks, such as Schriver & Atkins 2010, chemical knowledge is presented in formulas qualified by explicit mention of environmental constraints, for instance as Effingham diagrams, that display the variations in reactions with temperature and atmospheric pressure. In this paper I want to show how this implicitly moves chemistry into the domain of affordances.

2. Affordances: Gibson's Innovation

The concept of affordance was introduced and the word itself coined by J.J. Gibson in the 1950s. It was more fully developed in his later study of visual perception (Gibson 1967). It was conceptually linked to practice through Gibson's suggestion that seeing something was seeing what it could be used for by an animal, including a human being. A knife can be seen as affording cutting in the context of bread. A frozen lake can be seen to afford walking to a wolf but not to the elk it is pursing and so on. There is what is perceived, there are the action possibilities that are perceived by the relevant agent and there is the context in which the perception of an affordance occurs. The actor or agent is an ineliminable component of the content of the situated affordance concept, as is the material context in which a perception of an affordance occurs. According to Turvey (1976, p. 175) "Gibson denied that affordances are simple phenomenal qualities of subjective experience. To the contrary, he assumed that they are real properties of the environment relative to an animal [a person, an experimental apparatus *etc.*]; they are real [dispositional] properties that imply the complementarity of an animal and its surroundings." Nevertheless an affordance is a display of a disposition, but a disposition of what?

The notion of affordance has since been expanded to include the results of more mechanistic analytical procedures exercised on a target substance. It was in this latter sense that the concept was first applied to the analysis and description of phenomena produced in experimental science (Harré 1986). Agent, instrument, and context were three components of a hybrid being and all three components were needed for such a being to be the bearer of an affordance for a knowledgeable experimenter. A bit of steel, a piece of meat,

and a butcher are all required to complete the hybrid being to which the 'cutting' affordance can be ascribed. Only in the total set-up can a disposition to divide a chunk of meat exist, and perhaps be realized as the butcher serves a customer. By a natural further extension we can talk of the knife affording cutting and the whole set-up ultimately affording a steak; 'affordance' comprehends both process and product, as dispositions are progressively realized. A cloud chamber and a radioactive source afford tracks. By assembling a bath of molten sodium hydroxide, a battery, and electrodes, Humphrey Davy created a material set up that afforded the isolation of sodium metal, even if only momentarily. He did not set about an empirical test of Berzelius' electrostatic foundation for chemistry. It is hard to imagine how at that time such a research program would have been possible. Yet Davy was confident that his experiment would be worthwhile. Affordances *are* dispositions of such hybrid beings as the triad {Davy – electrical circuit – molten sodium hydroxide}.

Adopting the concept of 'affordance' to analyze the nature of chemical studies, it becomes clear that chemical 'facts' are attributes not of an independent world revealed by the use of apparatus, but are dispositional properties of a hybrid entity – an indissoluble union of apparatus, experimenter, and world. Of course, apparatus can be switched off, dismantled, washed up and put back in the store room. The laboratory assistant goes home at the end of the day. However, when the apparatus is being put to use by a chemist it is related to the world in such a way that the phenomena it displays can exist only as the apparatus is integrated materially into the world. It is a banal truism to remark that absent the apparatus the phenomena of chemistry do not occur but it is an important philosophical insight to see that they do not make sense either. Absent the world the phenomena do not occur nor do they make sense merely as attributes of the equipment. The hybrid of world-apparatus-experimenter is at the core of the meaning of the vocabularies we use for describing chemical phenomena. Again it is a banal truism that phenomena are only what they are in the eyes of an observer, but it is important to acknowledge the implicit presence of the apparatus as well. It is not a transparent window on the world.

The affordance resolution of seemingly paradoxical experimental discoveries supports and interprets Bohr's 'complementarity' way of linking the incompatible pairs of phenomena thrown up by experiment. The particle-wave duality is resolved and freed from any suggestion of paradox by treating the seemingly contradictory attributes of basic material beings as paired affordances linked to distinct apparatus-world set-ups. Llored's studies of points of view embodied in various patterns of study in environmental chemistry show that there is a kind of complementarity in that different environments coupled with chemical procedures yield different products (Llored &

Harré 2014). The constitution of the target substance cannot be recovered reliably and uniformly by projecting these products as constituents because their production is intimately bound up with the circumstances. These examples look simpler than they are because there is a strong presumption that the atomic structure of the target molecules involved in the reactions are supposedly already known.

3. Mereological Fallacies

The idea of a specifically mereological fallacy was introduced by M.R. Bennett and Peter Hacker (2003) in the context of a critical evaluation of the claims of neuroscience to be the inheritor of the flawed domain of empirical psychology. It is a fallacy, they argued, to ascribe an attribute of a whole animal (human being) to any of its parts. Thus a person thinks or remembers, but it is a fallacy to say that the cerebral cortex thinks, or the hippocampus remembers, and so on. Germane to the chemical sciences there is another mistaken inference pattern that purports to link the attributes of parts with those of wholes of which they are constituents. There is a second 'mereological fallacy'. It is the fallacy of taking the products of an experimental analysis of a substance or entity to be components of the inner structure of that substance or entity. How are such mereological fallacies of this type diagnosed? Only in some cases are such inferences fallacious. Let us call any inference from products to constituents of what has been analyzed the 'mereological projection'.

The test for whether a certain mereological projection is a fallacy requires a consideration of the metaphysical compatibility or incompatibility of the nature of the whole entity with that of its proposed constituents. One suggestion might be to compare criteria of identity and individuation for the two components of a mereological projection – products and constituents. For example, atoms and the molecules of which they are presumed to be constituents, share a spatio-temporal basis for individuation and identity. However, this criterion pattern is not shared with electrons, particularly spatio-temporal continuity in relation to identity.[1]

In inferring from electromagnetic products, such as electrons, as affordances of some specific procedure, to electrons as electromagnetic constituents of atoms on which that procedure was exercised to serve as the basis for the understanding of such basic chemical phenomena as bonding, starting with G.N. Lewis (1916), care must be taken to examine the unacknowledged presumptions of identity and individuation on which the validity of such inferences depend. A close look reveals that while electromagnetism in atom-

ic chemistry is the source of powerful working models of chemical systems, it is not a device for creating verisimilitudinous representations. This is a crucial distinction in analyzing any intellectual endeavor (Harré 2006).

But on what basis can we distinguish an inference from product to constituent that results in a verisimilitudinous representation of the nature of a chemical species from a similarly looking inference that provides no more than the content for a heuristic model? Because the internal structure and constituents of atoms cannot be observed without the use of probes, the distinction cannot be made empirically. At best we are presented with affordances. Chemistry is now an electromagnetic science built on a metaphysics of energy fields of differing density. It has long ceased to be based on a simple mechanical interpretation of chemical phenomena à la Dalton, nor on the interactions of moving charges drawing on both classical and relativistic mechanics and electromagnetism from which such concepts as 'spin' were derived, à la Bohr. As Llored and I tried to show (2014) the issue is one of presuppositions, that is of related practices and propositions which it would not occur to anyone to query. To cast doubt on relativity theory and quantum mechanics is at best eccentric, and worst mad.

4. Hinges: The Third Wittgenstein

The simplest picture of the content of any body of knowledge includes presumed conceptual relations displayed in *a priori* truths such as 'causes precede their effects', and explicit empirical facts, presented as *a posteriori* truths such as 'acid plus base yields salt plus water'. Such a simple picture is probably used by most people, including chemists, when they reflect on the logical status of chemical knowledge. But reflection suggests that every field of endeavor from gardening to rocket science involves unacknowledged grounding of practices and unacknowledged adherence to empirical truths *functioning as a priori foundations* for conceptual and material practices. Both practices and propositions are expressions of something deeper which is revealed only in such expressions and practices. These are Wittgenstein's 'hinges' (Wittgenstein 1974).

Hinges are not themselves forms of life. They are the basis of hinge practices, the core activities of forms of life, but at the same time they are also sometimes expressed in hinge propositions. Wittgenstein's argument in *On Certainty* is aimed at making clear that a hinge proposition is not to be taken as a statement of an item of knowledge, but expresses something of which we are certain. For the most part our lives are lived on the basis of certainties rather than on the basis of items of knowledge.

The development of 'hinge' studies as a new dimension of Wittgenstein's thought has been opened up by a number of scholars led by Moyal-Sharrock (2007). To see how Wittgenstein's thought developed it will be useful to review briefly the progression in his account of the constraints on intelligibility of discourses and rationality of practices. In the *Tractatus* Wittgenstein built his technique of resolving the endless repetition of insoluble philosophical problems by proposing a highly abstract and rigid 'language' with which problem free propositions could be constructed, the meaning of which was clearly fixed by reference to corresponding clusters of objects, and by the use of logic as the organizing principles of empirical discourses truth could be preserved. This was the doctrine of logical atomism. All other uses of language were expressions of opinion, of faith, of aesthetic appreciation. Philosophical problems could not arise.

In the 1930s Wittgenstein realized that the source of the deepest philosophical troubles, the conceptual mistakes that kept repeating themselves to us as philosophical problems, was the adoption of words from a domain in which they were at home for use in new contexts, such that subtle mistakes in the meanings of words in their original contexts were transferred to the new contexts and confusion inevitably occurred. The appearance of intractable philosophical problems, such as how free will is possible in a deterministic world, how the immaterial mind can be in interaction with the material body, and so on came about by misunderstandings of the everyday grammars of such words as 'free', 'will', and 'mind' by philosophers. Once one could be brought to see that words like 'mind', 'belief' or 'thought' were not nouns denoting substances, material or immaterial, the temptation to explain the differences between mental and material attributes of people in terms of some version of the concept of substance dropped away. At the same time, anticipating a deep insight of later post-modernists, Wittgenstein insisted that, having shown that one arm of a dichotomy was incoherent, it was also a mistake to fall back on the other as the exclusive foundation of supposed knowledge in the original field. New dichotomies are possible and perhaps enlightening. The disciplinary foundation of the later Wittgenstein is the pragmatic adequacy of the grammar of working languages.

The concept of a hinge refers to deep presuppositions of culturally distinctive pattern of thought and action that are expressed in certain hinge propositions, propositions that we are reluctant to abandon (that 'stand fast for us'), and in certain hinge practices, patterns of action of which we are completely confident.

The concept of 'hinge' is similar to but importantly different from the concept of 'background knowledge'. The very idea of 'knowledge' includes the contrasting idea of the possibility of error. Nor is it equivalent to the vague concept of *zeitgeist*, the 'spirit of the times'. Hinges are concretely

realized in particular practices and propositions. Hinge studies bring out what the people of a certain era were *completely confident* in believing and doing.

Hinges may change under two historical forces. A community may have begun to express the hinges that underpin their way of life as explicit propositions, and perhaps to subject them to empirical tests. New practices may emerge that are the most salient ways of living of a new form of life, perhaps by trial and error. Unlike the somewhat similar insight that Thomas Kuhn expressed in the notion of paradigm shift, hinge changes are matters of certainty, confidence in what one is doing, rather than in developments of knowledge of scientific truths.

The third Wittgenstein, by attending to the role of hinges, introduced another disciplinary matrix for philosophical clarification of the many ways language and other symbolic systems are used. What would be the result of bringing to light the unexamined taken-for-granted basis of the normative practices with which we carry on our lives? And how could this be achieved? Moyal-Sharrock (2007) has devised a useful terminology to describe the work of philosophers in analyzing hinges. Every hinge practice has a propositional doppelganger, the relevant hinge proposition. Both practice and proposition are grounded in and express overtly a tacit realm of hinges. Wittgenstein refers to the way that the hinges of a door remain stationary while the door turns, changing its role in the world from closed to open, from a barrier to an opportunity for entrance. The hinges of the human world at any one time remain unchanged and unacknowledged while the lives we lead, the practices we carry on and the propositions we believe in change. When we do formulate a hinge proposition we find that it is a putative empirical fact which no one has ever doubted or brought into question. One's own gender is a hinge that underlies everything that one does. But it is an empirical fact and it does make sense to query it as a matter of fact – for example the people who come to realize that really they are of the opposite sex to their anatomical gender. Shared hinges are the condition for the intelligibility of the propositions of a discourse and its doppelganger practices.

The 'third Wittgenstein' point of view fits nicely on to a practice-oriented view of chemistry. Chemistry can be thought of as changing repertoires of practices for the transformation of material stuffs into other material stuffs – descriptions of what happens when these practices are employed are mediated by propositional doppelgangers which currently describe an electromagnetic world as they once described a taken for granted corpuscularian world. Electromagnetic hinges underlie much of modern chemistry as the basis not only of practices but also of theories in chemistry. The deep hinge could be expressed in a hinge proposition something like this: 'This is an electromagnetic world'. G.N. Lewis would surely have taken this for granted, but if pressed

I daresay he would have said that this proposition was an empirical truth. He published his ideas about chemical bonding with *complete confidence*. It contrasts with the deep hinge that was expressed in the hinge proposition: 'This is a mechanical world'. The latter could be taken to be an empirical truth presumed in chemical discourse and chemical practices in the centuries that chemists used the corpuscularian point of view with *complete confidence*, from Robert Boyle to John Dalton. The chemical practices of Humphrey Davy and the theoretical speculations of Berzelius started the slow shift to a chemistry in which both hinge practices and hinge propositions expressed an electromagnetic world as the deep hinge on which the practices of chemists turned. Confidence in the Daltonian way slowly seeped away.

We can now see the Aristotelian-Galenic Four Elements as a deep hinge expressed in a broad cluster of practices, such as bloodletting, smelting iron ore with charcoal, and associated discourses all resting on empirical doppelganger propositions such as 'a healthy body requires a well-tempered pattern of the hot, the cold, the wet, and the dry'. Such propositions expressed a common hinge in antiquity and after. Then the thought that the world might not be a four element universe was unthinkable and so unable to be examined empirically.

Corpuscularianism, a view of the world as ultimately a swarm of individual entities forming contingent but disruptable clusters, was a hinge tacitly underlying radical thinking in the seventeenth century in England. It was expressed in propositional form in political writings such as those of Thomas Hobbes (1651). Robert Boyle gave propositional expression to the corpuscularian hinge in his declaration that that the material world consists of clusters of corpuscles that differed only by their bulk figure, texture, and motion (Boyle 1661). So far as I know he was the only chemist of the era to devise hinge practices formulated as explicit doppelgangers of the hinge propositions of his version of the world with his experimental program to test the corpuscularian philosophy empirically (Boyle 1667). Corpuscularianism had been taken for granted in the writings of seventeenth century thinkers such as Thomas Harriot, but Boyle (1667) began to treat it as an *a posteriori* claim, undertaking his experimental program as described in *The Origine of Firms and Qualities*. The current electromagnetic propositions (descriptions of electron orbits, for example) could be interpreted as propositions linked to a hinge proposition, 'this is an electromagnetic world', to be paired in a philosophical commentary with electromagnetic practices (for example the Stern-Gerlach experiments) as expressions of the very same hinge . Once again the hinge interpretation would lead us to see Stern setting up his equipment with complete confidence, rather than worrying whether electromagnetism was true.

As philosophers of chemistry we can describe clusters of distinctive hinge practices and their doppelganger hinge propositions such that adopting one cluster of practices and propositions expresses the current deep presuppositions on which confidence in chemistry is to be built.

5. Iconic Models: Hesse's Analysis of the Sources of the Content of Scientific Discourses

The three concepts we have studied so far, affordances, hinges, and mereological fallacies, are tools for the investigation and assessment of the status of the content of scientific discourses that purport to describe not only observable phenomena but also possible phenomena that are beyond the reach of even the enhanced senses. Bacteria invisible to Francis Bacon are readily viewed by school children thanks to the microscope. But electrons are viewable by no one. The solution to the problem of identifying the sources of content for theoretical discourses was already available in the 1950s, but it seems simply to have been forgotten (Hesse 1963).

This was surely in part due to the dominance of 'logicism' in philosophy, the Russellian doctrine that philosophically pertinent aspects of a discourse are exhaustively covered by a display of the logical form of the propositions of that discourse. This led to the neglect of the fundamental question of the origin of the content of scientific discourses. This neglect is illustrated starkly by the almost exclusive attention to formal models in philosophy of science, from Hempel's (1965) account of scientific explanation as deductive inference to Pearl's (2000) discussion of causal mechanisms in terms of sets of propositions. Pearl's recipe for assembling a cluster of statements which would serve as a description of a causal mechanism, represented by an iconic model, included a description of conditions extrinsic to the mechanism, a description of conditions intrinsic to the mechanism, and an account of the components of the mechanism itself and how they interact. Thus for a clockwork device to operate a switch on a bomb and so cause an explosion, the atmospheric and other environmental conditions must be right, the spring must be wound up and the gears and cogs must mesh in the right ratios to smoothly transmit motion through the mechanism. A similar pattern of requirements would be needed to justify the claim that the heat in the oven caused the bread to rise, via the mechanism of fermentation. More complex chemical example can be tackled in the same way. A recent slippage in terminology uses the same word 'model' both for the set of propositions descriptive of a mechanism as convenient interpretation, for example for testing the consistency of a mathematical expression of a theory, and also for taking a

mechanism as an analogue of whatever is the real casual process. In the 1950s and 1960s it was more or less taken for granted that scientific theories were descriptions of actual or possible causal mechanisms responsible for the results of observation and experiment. Some of these mechanisms were observable but others lay beyond the boundaries even of the enhanced senses. Failing an observational and/or manipulable access to realms of the unobservable (Harré 1986, Hacking 1983), the nature and uses of 'iconic models' were studied as sources of empirical content for explanatory theories. Pearl offers no account of where the content of his propositions come from.

It soon became clear that while some iconic or representational models were taken to be verisimilitudinous representations of unobservable entities, properties, processes, and mechanisms, other served only a heuristic function, giving thinkable content to the bare bones of logical, formal algebraic presentations of theories. This distinction had already been clearly explained and illustrated by N.R. Campbell (1920) in the early 20th century and forgotten.

To what could an investigator and particularly a researcher planning a new series of experiments refer to decide whether a model was worth taking seriously as a possible reality, that is as a plausible representation of a so far inaccessible realm of reality on a par with the aspects of the world already investigated? The metaphysical presumptions of the era were cited as the core of plausibility criteria. In the era of the neglect of the content of scientific thinking in favor of logical forms, this rather vague proposal was not further studied.

The semantic system[2] by the use of which new content was created for theoretical work turned out to involve a basic distinction between the relations of a core model at the heart of a theory to its source, as an analogue of something already known, what it was modeled on, and the target, what it was used as a model of, the unobservable process, *etc.* from which the theory in question derived its possible empirical content. These rather imprecise analogical links were sharpened by presenting model target and model source pairs as subtypes of a common supertype. As such a pair of subtypes would share some but not all of the common attributes derived from the supertype. The supertypes of an era could be thought of as subtypes of a yet more general supersupertype, expressing the background assumptions on which the semantic developments of the meaning of the concepts of a theory rested (Way 1991). In this way iconic models were created that were closely related to presumptions about the nature of the processes they were introduced to explain, their intelligibility guaranteed by their pairing with a known mechanisms via the common supertype they both realized. For example, the content of Darwin's evolutionary theory can be seen as a subtype of the supertype 'breeding selection process'. The source was the selection practices of

farmers and gardeners in picking out the animals or plants to be the breeding stock for the next generation, and the target the unobservable process of selection of breeding individuals by natural forces. Domestic selection and Natural selection were both subtypes of the supertype 'selection of breeding stock'.

The creation and management of iconic models as the response to the realization that a certain analytical procedure does not extract products that could serve as constituents of the beings that have been subjected to that procedure, completes the analytical tool kit for philosophy of any science, in particular chemistry. Weaving together the four strands of this discussion we can see that exploring the supertypes that determine the way iconic models are created is tantamount to a study of the hinges that shape the doppelganger pairs of empirical practices and theoretical propositions of an era. Culturally local hinges play a key role in the selection of models for either heuristic or realist purposes.. These are rarely explicitly examined, and then only when the old system of paired practices and propositions seems to run out.

6. The Philosophical Shape of Any System of Chemistry

Unknown to most chemists in the last one and a half centuries of the dominance of some form of atomism is the forgotten calculus of chemical operations developed by Sir Benjamin Brodie, Oxford chemist of the mid-nineteenth chemistry and one of many hostile to atomism (Brodie 1866). Brodie's chemical system can serve as an illustration of the 'affordance-hinge-mereological fallacy-model' tool kit to reveal the implicit conceptual structure of a fragment of science. He advocated a view of chemistry as the accumulation of repertoires of laboratory practices which changed the qualities and masses of standard units of a spatio-temporal continuum. The products of chemical operations were defined by analytical or synthetic operations according to the simple rule: same procedures yield the same products; different procedures yield different products. Chemical operations were defined by what they afforded as operands on a region of space. Chemical formulae had two matched interpretations – as descriptions of before and after properties of the products of the operations that were required to change some of qualitative properties of a standard region of space, and as arithmetical rules for calculating before and after weights of the reagents and their products.

Brodie did not query the method of distinguishing of material substances exhaustively by their observable qualitative and quantitative properties. As in any version of trope chemistry, that is chemistry as the study of the way to

change nothing but the observable qualities of material stuff, the products-constituents fallacy could get no grip. The products just are the constituents. The qualitative products of chemical operations just were the 'parts' of the resulting material stuff. If Brodie had ever thought of expressing his chemical system in terms of a model, it would perhaps have been changing the color of a piece of cloth by dyeing it. Brodie was completely confident that his system captured the essence of chemistry. *We* can propose a hinge proposition – there are no material properties other than observable qualities and measurable relative weights – and can interpret his chemical operations as doppelganger hinge practices.

The point of introducing Brodie's chemistry is simply to show that even when one deep chemical hinge is dominant, its propositional expression only masquerades as an *a priori* constraint. It is, in the largest sense, an empirical question as to whether the world is electromagnetic or technically speaking a world of tropes, that is surface qualities of the world as observed by human beings, and chemistry the science of the transformation of such qualities (Harré 2009). However, his system failed to account for some common cases where these simple principles were not satisfied – for example isomers. The doppelganger practices failed to fit with the conceptual descriptions. 'Trope chemistry' is conceptually incoherent considered in the framework of the four fold conceptual tool kit I have been describing in this discussion.

The core of chemistry as a science is an open repertoire of practices, and what executing them affords. Affordances are attributes of hybrid beings, indissoluble groupings of material stuff into apparatus/world complexes, including the people who manage and manipulate them. Both apparatus and the material substances that the experimenter uses to explore the *Umwelt*, the human environment, are constituents of the world, which can easily be physically separated but to none of these parts can an affordance be properly ascribed. Textbooks like that by Schriver & Atkins (2010) include data about the differences in chemical reactions with differences in the environment. In discussing the reactions of molecular hydrogen, Schriver and Atkins remark that in general these reactions are slow. There are conditions under which they are more rapid. These include activation by homolysis (symmetric bond breaking) on a metal surface, heterolytic dissociation by a metal ion, and initiation of a radical chain reaction. They make no mention of the knowledge and personality and other aspects of the character of the experimenter, nor do they describe the apparatus in which molecular hydrogen affords these reactions. These are analyses of chemical phenomena in terms of partial affordances. There are cases in which the experimenters' skills are important as contributors to the affordances of the laboratory procedures, such as those described by Latour & Woolgar (1979). Morley's steadiness nicely complemented the excitability of Michelson in the early hours of the

morning at Euclid Avenue, Cleveland, Ohio. Unlike the textbooks of a hundred years ago, such as Mellor (1914), the apparatus in use is not described nor its manufacture and assembly revealed in most modern texts.

What is taken for granted for the intelligibility of the practices that constitute the core of a discipline is manifested in the practices and in the doppelganger propositions expressing the same taken for granted content whatever that might be.

Realism in chemical theory requires the developing of working distinctions between legitimate product-constituent inferences and fallacious ones. By making use of certified mereological inferences, accounts can be built up to partially explain why chemical practices have the affordances they do. These accounts are partial because there can be no guarantee that conditions are the same case after case. The entity to which the attributes revealed by an analysis are ascribed is not the apparent *analysandum*, but an indissoluble hybrid of the apparent *analysandum* and the equipment required to carry out the analysis. The result of each analysis of the apparent *analysandum* conducted by the use of different analytical equipment in a different spatio-temporal environment is a property of a different hybrid entity. How much of the total environmental setting must be included in the hybrid? J.J. Gibson took the environment to be stable, and irrelevant as a contributor to the characteristics of an affordance, since it was an equal contributor to every affordance of the kind in question. The affordances of solid ice characterized one 'world' and those of liquid water another, that is to say ice affords walking to a wolf while water does not.

To advance chemistry we construct *models* of the structures of molecules, atoms, and of the processes of analysis and synthesis which are the focus of chemical practices, on the basis of *mereological inferences*. The evidence for these inferences comes from *affordances*, which are disciplined with respect to realist or heuristic interpretations by attention to *hinge-practice and hinge-proposition pairs* which incorporate the working metaphysics of an era. If the mereological projection of the highest order supertype in the contents of the best working model fits well with the dominant hinge via successful practice and unified propositional descriptions of a hypothetical mechanism then the theory is plausible, but if it does not but still presents a coherent picture then it may serve a heuristic purpose.

Instead of thinking of scientific research as the implementing of a hypothetico-deductive logical pattern, we should be thinking in terms of what a certain apparatus-world complex affords an experimenter. High energy physics experiments afford tracks in photo-emulsions, 'jet' trails in cloud chambers, which are also afforded by computer simulations from data recovered as the products of collisions, and so on. These are almost automatically interpreted as the paths of electrically charged bodies, electrons. In interpreting

'tracks' as the results of the motion of otherwise undetectable charged bodies, a taken-for-granted background was implicated. It seemed too obvious to be remarked that tracks are the products of ionizations produced by moving electrically charged corpuscles. Why do we take it for granted that in addition to the tracks the set-up also affords electrons as the intermediaries in the realization of the possibilities of the experimental arrangements? This is an inference the grounds for which are never examined. To do so requires bringing to light the hinge-propositions expressing the taken-for-granted beliefs and doppelganger hinge-practices of both of which the chemist or physicist as theoretician and as experimenter is entirely confident.

Notes

[1] All such inferences are approximations, of course. In certain circumstances atoms can be diffracted.

[2] The 'semantic' interpretation of theories proposed by van Fraassen, for example, is a version of the logicist view and not a revival of theorizing as model-making.

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