Kant's *Critique of Judgment* and the Scientific Investigation of Matter

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Abstract: Kant's theory of judgment establishes the conceptual framework for understanding the subtle relationships between the experimental scientist, the modern instrument, and nature's atomic particles. The principle of purposiveness which governs judgment has also a role in implicitly guiding modern experimental science. In Part 1 we explore Kant's philosophy of science as he shows how knowledge of material nature and unobservable entities is possible. In Part 2 we examine the way in which Kant's treatment of judgment, with its operating principle of purposiveness, enters into his critical project and underlies the possibility of rational science. In Part 3 we show that the centrality given to judgment in Kant's conception of science provides philosophical insight into the investigation of atomic substances in modern chemistry.

Keywords: *Kant*, *judgment*, *purposiveness*, *experimentation*, *investigation of matter*.

Introduction

Kant's philosophy of science centers on the problem of how it is possible to acquire genuine knowledge of unobservable entities, such as atoms and molecules. "What and how much can the understanding and reason know apart from all experience?" (*CPuR*, Axvii). This raises the question of the role of experiments in the knowability (*Erkennbarkeit*) and the experientiality (*Erfahrbarkeit*) of nature.

Kant's insights into the character of scientific experimentation are not given the hearing they deserve. We argue that Kant's theory of judgment establishes the conceptual framework for understanding the subtle interactions between the experimental chemist, the modern chemical instrument, and molecular substance. His principle of purposiveness, which governs the general faculty of judgment, plays a particularly significant, if implicit, role in contemporary experimental chemistry. The investigation of nature through

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instrumentation requires a process of "weighing matter" which must rely on judgment (*OP*, 21, 408-409).

In Part 1 we summarize, without critical analysis, four theses of Kant's philosophy of science concerning the experimental detection of unobservable entities. In Part 2 we argue that Kant's theory of judgment, and especially his principle of purposiveness, is central to his critical project and underlies the possibility of rational science. In Part 3, revisiting his philosophy of science (in Part 1), we show how purposive judgment guides the use of chemical instrumentation in the contemporary investigation of matter.

I. The Knowability of Unobservables

How can scientists acquire knowledge of unobservable processes, which presumably underlie sensory phenomena? In *CPuR* Kant addresses this question by offering a *transcendental critique* of the *a priori* conditions of all possible experience,[1] which becomes the starting point for all knowledge of physical bodies in general. Knowledge of bodies does not demand immediate perception of the actual objects before us, but only the mediated connection between objects and some actual perception (*CPuR*, A225/B273). Kant not only shows how knowledge of the material world and unobservable entities is possible, but, we argue, how such knowledge is enhanced through the use of scientific instruments. An instrument can serve as such a mediation or connection between an unobservable entity and an actual perception. If this connection instantiates known empirical causal laws linking the theoretical entities to things perceived, then knowledge of unobservably small phenomena can be attained (H. Duncan 1986, 279).

To develop this theme of linking theoretical entities to perceptions, four sequentially-ordered theses can be gleaned from Kant's work.

(1) The given data of perception can be objects of possible experience only through empirical motion (as the movable in space).

For Kant empirical motion is always relative to a given space; absolute motion and absolute space are fictions. The connection of unobservable entities to actual perceptions requires a change in the sequence of appearances. Kant addresses the notion of change underlying these appearances in his Analogies of Experience (*CPuR*, B218ff./A177ff.). An analogy of experience is an empirical rule according to which a unity of experience arises from perception (*CPuR*, A180/B223). Experience, or empirical knowledge of appearances, is possible only through the temporal succession of homogeneous units of experience based on the relation of cause and effect (*CPuR*, A189/B234).

To explain empirical motion Kant develops a dynamical conception of matter (*MAdN*, 477).

> (2) Empirical motion, as described in (1), is causally explained by the forces of repulsion and attraction, comprising the metaphysical character of matter.

To be an object of experience, a physical body encompasses a system of powers, repulsion and attraction, in relation to other bodies (*MAdN*, 523). Repulsion is not identical with the perceptions of resistance, but is, by definition, causally responsible for such perceptions. Repulsion gives matter its power to resist possible intrusion by another body which may press into "its space" (*MAdN*, 498). To prevent the universe of bodies from flying away from each other indefinitely, a force of attraction is necessary. Attraction is the force of movement of one body toward another body (*MAdN*, 499). So, the entire physical universe is a grand composite of continuous pulsations, accumulating repulsions and countervailing attractions.

In order for empirical matter to become experience, something must be thought through the understanding, according to principles for the construction of scientific concepts (Plaass 1965, 300).

> (3) Such causal forces, as described in (2), must be subject to conceptualization through theoretical judgments in order for a science of corporeal nature to be possible.

The possibility of such forces is evident in their cognitive anticipation, necessitating scientific judgments. For Kant a force is a body's power, or tendency, to exhibit movement under certain conditions. This power can be conceived only through the following hypothetical judgment: when subject to a "compressing intruder," matter will resist penetration and generate an opposite motion on the intruder. The judgment underlying the concept of attraction is roughly as follows: given a certain proximity of two bodies, the distance between such bodies will decrease. Thus, the scientific investigation of empirical matter requires the systematic order that is facilitated by judgment-power.

The union of nature's systematic order and the mind's cognitive faculties underlies the possibility of experience.

> (4) The given data of perception can be objects of possible experience only through the unifying power of scientific judgments.

Thesis (4) is a conclusion from (1), (2) and (3). The possibility of perceptual data rests on certain transcendental conditions based on the laws of thought. The main target in the First Critique was a demonstration of the possibility of synthetic judgments *a priori*. In that work the conditions of the possibility of experience in general are likewise conditions for the possibility of the *objects* of experience, *i.e.* for possible empirical knowledge in general (*CPuR*, A158/B197). But only in the Third Critique, with its theory of judgment, does he complete his project of unifying consciousness and the objects of nature: "nature in its transcendental laws harmonize[s] with our understanding" (*CJ*, 233').

In the Preface of *MAdN* Kant gives two meanings to 'nature'. First, in its material meaning 'nature' refers to the totality of external objects of experience. Second, in its formal meaning 'nature' stands for the "internal principle of a totality of an existing thing" (*MAdN*, 467). Nature in this formal sense is not grounded on some unchanging essence of matter in itself but is "derived" from our subjective faculty. The first meaning requires a "doctrine of extended nature", the second requires a "doctrine of the soul" or thinking nature. These two conceptions of nature are united in scientific investigation: one can only look for (formal) nature in precisely all the things that belong to (material) nature (Plaass 1965, 223).

Here we confront a dilemma: In order to make knowledge claims of unobserved facts we need to establish a general metaphysics which requires an analysis of human consciousness.

II. The Centrality of the *Critique of Judgment* for a Metaphysics of Nature

A. Judgment and its Link to A General Metaphysics

In the *Critique of Pure Reason* Kant declared that the power of judgment is of greatest significance, more important than knowledge and reason, indeed "its lack no amount of schooling can make good" (A134/B174). To give judgment such prominence requires a reassessment of some aspects of Kant's transcendental philosophy, in particular his introduction of the principle of teleology (purposiveness) into his critical system. This system analyzes the sum total of the *a priori* structures of consciousness by means of critiques. Kant's three Critiques of the pure principles of consciousness become the fundamental *leitmotif* of his Critiques.[2] We hold that the inclusion of the *Critique of Judgment* adds considerable explanatory force, especially to the character of scientific judgment applied to the practice in contemporary experimental science. We suggest a more widely ranging perspective on Kant's theory of judgment to complete his general metaphysics, not fully grasped in post-Kantian scholarship, although Kant's metaphysical epistemology enjoys a general revival.[3]

Kant's theory of judgment provides a programme to show the link between a *system* of nature (natural science expressed in laws) and a *system* of experience (natural consciousness expressed in principles). In order for two self-enclosed systems to be united a principle common to both must facilitate the transition. Judgment, guided by its *a priori* principle of purposiveness, becomes the essential power to unite all the faculties of consciousness, but also and important for science, to provide the conceptual framework for uniting the conditions of knowing with a system of nature. The unity of nature and consciousness through judgment stands at the center of transcendental philosophy. Two related questions arise: (1) Is it possible to make claims about "extended nature" *before* an adequate analysis of "thinking nature" is established? and (2) What constitutes the possibility of a general metaphysics to give guidance to a separate, special metaphysics for corporeal nature? In the following passage Kant addresses both questions:

> All true metaphysics is taken from the essential nature of the thinking faculty itself .... Metaphysics is not borrowed from experience but contains the *pure operations of thought* [emphasis supplied] and hence contains concepts and principles *a priori*, which first of all bring the manifold of empirical representations into legitimate connection, whereby such a manifold can become empirical *cognition* [Kant's emphasis], i.e. experience (*MAdN*, 472).

For Kant thinking nature and its complete analysis (in critiques) is a prerequisite for any science and constitutes the general metaphysics which in turn must be concretized, or given sense and meaning by a special metaphysics of corporeal nature. Writes Kant:

> And so a separate metaphysics of corporeal nature does excellent ... service to general metaphysics, inasmuch as the former provides instances (cases *in concreto*) in which to realize the concepts and propositions of the latter (properly, transcendental philosophy), i.e., to give to a mere form of thought *sense and meaning*. (*MAdN*, 478; emphasis added)

A general metaphysics, based on a complete theory of consciousness, finds meaning only when applied to the methods and practices of science; there must be a reflexive link between them.

B. Judgment and Its Guiding Principle, Purposiveness

Kant's theory of judgment completes the critical business to unite the system of consciousness with the system of nature. The full problem of judgment as it gave rise to "knots and riddles" throughout Kant's precritical as well as critical writings cannot here be presented.[4] The elusive character of judgment rests on its mediating role as arbiter between two independent realms.

> An immense gulf is fixed between the domains of the concept of nature, the sensible, and the domain of the supersensible ... and no transition by means of

> the theoretical use of reason between them is possible. ... [So] there must after all be a basis *uniting* [Kant's emphasis] the sensible and the supersensible (*CJ*, 176).

Kant claims that this unity between two systems is provided by the power of judgment, guided by its principle of purposiveness (*Zweckmässigkeit*).

Kant defines judgment as

> the ability to think the particular as contained under the universal. If the universal (the rule, principle, law) is given, then judgment, which subsumes the particular under it, is *determinative*. ... But if only the particular is given and judgment has to find the universal for it, then this power is merely *reflective* (*CJ*, 179; Kant's emphases).

Judgment is protean and has a dual role. In its first role judgment determines its object by subsuming it under a given rule (*CPuR*, A132/B171). Judgment here is a "doctrine", lacking a critique. As determinative it is a categorizing activity, "marked out *a priori* by the understanding" (*CJ*, 180), a mere classifying role, subsuming particular appearances under universal rules already given. Strictly here it is not yet assessed in its activity to find the universal. Traditional readings of the First Critique, based on Kant's own assessment up to this juncture of his development, hold that transcendental philosophy is completed with the First Critique and thus presumed to provide a general metaphysics for use in a special one, such as natural science.[5] Kant himself applies the four functions of thought in the Table of Categories of *CPuR* to *MAdN*,[6] indicating his confidence in having completed a general metaphysics. However, even at the time of writing *MAdN* he recognized the difficulty in developing a special metaphysics for corporeal nature, because such a metaphysics required a mathematics for the dynamical forces of nature which presumably surpasses the capacity of cognition. Kant contends that the mathematics of the original forces of nature "lie generally beyond the horizon of our reason" (*MAdN*, 534). This difficulty is neither resolved in *CPuR* nor in *MAdN* and suggests a gap between empirical nature and a genuine metaphysics of nature. We suggest Kant's thesis of judgment, fully developed in *CJ*, offers a means of overcoming the difficulty.

Judgment's second function pertains to its formal reflective mode, which requires a principle not yet revealed in *CPuR*. This principle requires that we think of nature as comprising "things under possible (yet to be discovered) empirical laws" (*CJ*, 184). As in the First Critique the faculty of representation has its *a priori* spatio-temporal forms and the faculty of understanding its *a priori* categories, so Kant discovers late in his critical phase, that judgment as an independent power is equipped with an *a priori* principle, that of purposiveness. This principle is crucial to complete a critique of judgment, the last of the faculties, and only then represents the culmination of a general metaphysics. How does the principle of purposiveness guide scientific judgment?

When an object is given in experience, purposiveness can be presented in two ways, corresponding to the two functions of judgment, objective (material) and subjective (formal) (*CJ*, 193; 225').[7] We are concerned with the former, the objective-material function through purposiveness without which science is impossible. Objective purposiveness strives towards a conceptually coherent experience (*CJ*, 184). Kant's concern with the conceptual coherence of experience in its full universal range requires judgment's guiding principle of purposiveness:

> Through this [principle] we present nature as if an understanding contained the basis of the unity of what is diverse in nature's empirical laws ... [P]urposiveness of nature is a special *a priori* concept that has its origin solely in reflective judgment. For we cannot attribute to natural objects anything like nature's referring them to purposes, but we can only use this concept in order to *reflect* in nature ... (*CJ*, 181).

The principle of purposiveness of nature is necessary to unite the form of the object [in intuition] with concepts as to produce a cognition (*CJ*, 192), *i.e.* to produce a unity between a system of experience and a system of nature. With reference to scientific judgments, we can present purposiveness of judgment as having an *objective*-"real" or material basis, which refers "to a determinate cognition of the object under a given concept" (*CJ*, 192 and 225'). In contrast to aesthetic judgment, purposiveness here "has nothing to do with the feeling of pleasure in things, but rather with the *understanding* in our judging of them" (*CJ*, 193; emphasis added), or "we *think* the purposiveness before we *sense* it" (*CJ*, 225', Kant's emphases). The scientific investigation of nature presupposes a prior objective purposiveness that is inseparable from the sensed natural purposes.

> Hence we may regard ... *natural purposes* as the exhibition of real (objective) purposiveness, ... judged by understanding and reason, i.e. logically according to concepts (*CJ*, 193).

But how does purposiveness become a principle of nature such as to generate a unity of experience, that is, a unity of the observer and the observed? This requires a "transition"-filling the gap on *a priori* grounds between the metaphysical foundations of science, a pure product of thought, and nature. By Kant's own admission this remains unresolved and leaves the "transition problem," a pressing issue in contemporary scholarship.[8] How can nature unite with pure thought? Does nature possess an apriority of its own to make a transition possible?

We believe that for Kant the transcendental task of judgment in its reflective mode is to find the universal order *within* the particular givenness of natural processes. His theory of judgment, extended to modern scientific practices, resolves some of the earlier difficulties. The power of judgment in its reflective mode allows reason to increase its range of abstraction. Scientific investigation aspires always, if implicitly, to a universal order which, we submit, requires the teleological principle of reflective judgment. The experimental investigation of individual empirical objects always strives towards a universal understanding of nature, which, we submit, is generated by the experimenter's purposive judgment. For Kant every empirical investigation presupposes that nature, even in its empirical laws, "adheres to a parsimony suitable for our judgment and a uniformity we can grasp" (*CJ*, 213'). Such presupposition has its origin in the necessary principle of judgment, which guides every scientific experiment. The mysterious "third thing" of the First Critique is revealed as judgment and finds conceptual articulation in the Third Critique. Through reflective judgment the scientist thinks of nature as a system of empirical laws conform to his understanding, thus establishing a unity between nature and judgment:

> [For] not only does nature in its transcendental laws harmonize necessarily with our understanding ... [but] nature in its empirical laws harmonize necessarily with judgment. ... [This] harmony of nature with our judgment is there merely for the sake of systematizing experience, and so nature's formal purposiveness as regards this harmony can be established as necessary (*CJ*, 233').

These Kantian insights we now wish to show as relevant and evident in the use of modern instruments, products of judgment, which facilitate the subtle interaction between material nature and the scientist.

III. The "Design" of Nature through Scientific Instrumentation

The experimental chemist typically enters the laboratory with the following working assumption: molecular substance is ordered in ways that permit its "knowability," as if designed for experimental inquiry. This commitment to the systematic order of substance is a precondition of experimental investigation, without which chemical investigation would be impossible. The principle of the purposiveness of nature is an *a priori* condition of empirical investigation, in the sense that it unites the particularities of matter with a universal order produced by judgment.

To show how purposiveness of nature underlies modern chemical experimentation, we argue that Kant's requirements for the detection of unobservably small phenomena can be extended to modern investigations of atomic events.

Kant's theses (1) through (4) above offer philosophical insight into modern experimentation. But we avoid a simple and direct application of Kant's principles to modern chemistry, because Kant's philosophy of science is seemingly inseparable from his entire transcendental enterprise. To deepen the analysis between Kant's insights and modern practices we discuss briefly the rationale for using complex instruments in contemporary studies of atomic processes.

A. The Rationale for Chemical Instruments

Most modern instruments in chemistry are designed as systems for communicating information (Skoog and Leary 1992, 3). Information is retrieved when the specimen's atomic structure is sufficiently agitated to evoke a detectable reaction. The experimental chemist tricks the specimen to reveal its secrets. The specimen is poked, dissected, and disturbed, typically through a manipulating probe in the form of electromagnetic radiation (Lelas 1993, 429). We are reminded of Hacking's dictum: the experimenter sees with a microscope and not through one (1983, Chapter 11).

Consider how a modern absorption spectrometer is designed. Commonly used for identification and structure elucidation of chemical substances, these instruments are designed as information-processing devices for measuring the physical response to the bombardment of radiation on the specimen. A beam of electromagnetic radiation is emitted from a source and then passes through a monochromator, which is a series of optical components such as lenses and mirrors. The monochromator isolates the radiation from a broad band of wavelengths to a continuous selection of narrow band wavelengths. The radiation then impinges on a sample. Depending on the molecular structure of the sample, various wavelengths of radiation are absorbed, reflected or transmitted. That part of the radiation which passes through the sample is detected and converted to an electrical signal, usually by a photomultiplier tube. The electrical output is electronically manipulated and sent to a readout device, such as a computer, controlled video display or printer/plotter (Rothbart and Slayden 1994).

When using this apparatus, the experimenter's primary attention is the signal, as the source of information. The movement and transformation of the signal is determined by the following three types of mechanisms. First, the signal generator is a system which produces the signal by irradiating the sample, following the bombardment of photons. Second, a transducer or detector is a device that converts one kind of signal to another. Sometimes this requires a tremendous magnification of the signal's strength. Third, the readout device converts a signal to a form that is understandable to humans (Skoog and Leary 1992, 3-4).

Like most modern instruments, the absorption spectrometer never provides a pure vision of substance in its pristine and inert state. Our secret wish to access the thing in itself must be suspended. The chemist's closest contact to atomic processes centers on an artificially-generated event, which we call the experimental phenomenon. This phenomenon is crafted from the interface between apparatus and specimen in the signal generator. The signal generator localizes the entire interaction between the apparatus and specimen to a single point in space and time. This single point has profound philosophical significance, in that it represents both the specimen's real atomic structure and the scientific thought determining the instrument's design. The primary epistemic relationship between chemist and substance centers on this point. So, Hacking correctly describes the instrument as a tool used to manipulate the specimen in ways that produce detectable effects. He goes on to argue that it is engineering, not theorizing, that exposes nature's secrets (1983, p. 263). No theoretical abstraction is needed when the specimen is manipulated by the skilled technician. However, Hacking seriously underestimates the indispensability of theoretical doctrines in the use of modern instruments. His claim that a technician can manipulate an apparatus without theoretical background is quite misleading and epistemologically uninformative; sophisticated instruments reflect the advanced state of theoretical developments from a wide array of disciplines. Most facets of instrumental design, calibration of measurements, and data analysis rest on the endorsement by the scientific community of many abstract principles. Without such an endorsement modern instrumentation is impossible.

Scientific principles not only underlie the use of modern chemical instruments, but they also determine how the specimen is conceived during the experiment. Rather than removing theoretical influences from the experiment, as Hacking argues, modern instruments are used in ways that presuppose theoretical assumptions about the specimen. More than just a collection of metal, glass, and wire, the instrument operates as a channel for theoretical ideas. Metaphorically speaking, the instrument functions as a non-transparent medium for "projecting" scientific judgments from the experimental background to the foreground specimen (Cassirer 1923, Chapter VI). When the experimenter selects a specimen for a spectrometer, certain highly theoretical properties are exploited. Various categories, distinctions and relations from the physical sciences must be attributable implicitly to the specimen in order for the experiment to be performed.

The act of identifying a specimen for a particular experiment has important metaphysical implications. The experimental chemist is implicitly committed to those ontological categories and processes which must be realized in order for the experiment to succeed. When we ask "What is the underlying order of nature?" we must also ask "To which conception of matter are we committed when we perform an experiment?". Nature's underlying order is revealed by the commitments we make in the production of experimental data. Our use of the modern instrument is a positive expression of such a commitment. The instrument is not the obedient servant to the ruling order of nature; modern instrumentation presupposes a universal order for the possibility of empirical investigation. During the performance of the experiment, particularities of the specimen are transcended at every turn to reveal a universal conception of matter.

The design of modern chemical instruments implicitly places constraints on the character of the specimen. During the experiment, the substance under examination is operationally defined by its reactive capacities, understood through various dynamical models of energy enhancement and exchange. In the laboratory the specimen is not passive; it is reactive, determined by its potential responses to stimuli. A new object is understood by its possible performance. According to Bruno Latour, reality is defined in the laboratory by its capacity to resist intrusion by external forces (1987, 93). We prefer to say that reality is defined through its capacity to *permit* intrusion from external forces, and to *react* in ways that generate detectable effects. As a precondition of most chemical experiments, matter is operationally understood as a reactive system whose immediate function in the laboratory is to generate signals. In this way substance is defined by its function (Cassirer 1923).

A body's reactive capacities are understood through its physical powers. A power is a tendency or disposition of a system to exhibit detectable effects under certain circumstances, as evident in the dynamics of electrostatic repulsions and attractions (Harré 1986, Chapter 15). Thus, the specimen's suitability for modern empirical examination centers on the specimen's dynamics following principles of physical science.

The vehicle for understanding the specimen's physical structure is typically the conceptual model. Comprising a system of variables and relations, categories and distinctions, the model functions as an idealized replica of "causally significant" processes in the environment (Rothbart 1997, Chapter 3). So, when a modern instrument is *designed*, a wide range of models from various physical sciences coalesce; when an instrument is *used*, variables and relations from these models are "projected" to the idealized understanding of the specimen. For example, the design and use of an absorption spectrometer assumes that certain dynamical properties known from electromagnetic models are extended to the experimenter's understanding of the specimen (Rothbart and Slayden 1994).

B. Purposiveness in Modern Experimentation

We can now address the Kantian underpinnings to the possibility of scientific evidence. In particular, the union of matter and mind in the scientific investigation of nature extends to the character of evidence through modern chemical instruments.

As a convenience, theses (1) through (4) from Kant's philosophy of science are repeated:

(1) The given data of perception can be objects of possible experience only through empirical motion (as the movable in space).

(2) Empirical motion, as described in (1), is causally explained by the forces of repulsion and attraction, comprising the fundamental metaphysical character of matter.

(3) Such causal forces, as described in (2), must be subject to conceptualization through theoretical judgments in order for a science of corporeal nature to be possible.

(4) The given data of perception can be objects of possible experience only through the unifying power of scientific judgments.

Each one of these theses shows striking affinity to four philosophical doctrines, presented below as (1') through (4'), concerning modern experimentation.

(1') In order for experimental data from modern chemical instruments to be possible evidence of an unobservable process, the signal must undergo a succession of changing states (movements).

Again, when an apparatus is used, the focus of attention in the experimental foreground is the signal, rather than the specimen in its static state. The connection between the specimen's unobservable processes and the readout data is secured by the movement of the signal (Thesis 1'). From this movement the signal experiences various energy enhancements and transformations, beginning with the specimen/radiation interface and culminating with the production of data. Of course, the conception of empirical motion underlying Kant's (1) is quite different from the conception of transformation of a signal underlying (1'). Again, for Kant motion requires the time-directed sequence of given appearances; for contemporary physicists motion assumes the dynamical transformation of energy-states. Nevertheless, both (1) and (1') establish the need for a connection between the substance under investigation and the detectable data through a causally linked sequence of events. Knowledge of unobservably small phenomena can be achieved indirectly by retrieving data through physical 'movement' of the signal.

(2') The movement of the signal, described in (1'), is made possible from the specimen's dynamical properties familiar to contemporary physical sciences.

Again, the specimen retains certain capacities which are exercised during the performance of the experiment. In order for the bombarding photons to interfere with the specimen's atomic structure, the specimen must be susceptible to intrusion by radiation, and must have the capacity to generate a physical effect. During the experiment, the specimen functions as a dynamical reactive system of powers. (This thesis is not intended to apply to empirical studies of large-scale events.) Obviously, Kant's particular conception of movable force underlying Newtonian physics is a distant ancestor to the dynamic forces of modern physics, such as electrostatic repulsion and London attraction. But the currency of Kant's thought to contemporary chemical experimentation is evident in the specimen's function during the experiment. The experimenter highlights the specimen's potential to generate detectable effects, based on the specimen's powers.

(3') The dynamical properties, described in (2'), must be subject to theoretical conceptualization (scientific judgment) in order for a chemical investigation of atomic processes to be possible.

As the specimen is selected for experimental investigation, highly theoretical processes are anticipated. The specimen's dynamical character, as well as the range of possible responses, are known by the designers of the instrument through the use of theoretical models. Such models provide a conceptual understanding of the relevant causal processes. A hierarchy of categories and relations from electromagnetism are particularly central to this task. In this respect the physical real is united with the theoretical ideal in the performance of the experiment.

(4') In order for data from modern instruments to be possible evidence of an atomic event, theoretical constructions of various physical processes are necessary.

The data from a modern chemical instrument never yield a transparent (pure) picture of an atomic event. The desire for theory-neutrality approaches fantasy in this setting. Information at the readout reflects a highly theoretical union of instrument and nature, concerning the physics of radiation, the reactive capacities of the specimen, and the character of the resulting signal. These physical processes are real in nature, and they are accessible through the designer's cognitive constructions.

Underlying (4') is the principle of purposiveness, according to which the subject matter of science must be ordered in ways that permit its 'knowability', as if designed purposively for investigation. When modern chemical instruments are used, the specimen is understood as a dynamical reactive system, whose capacities are activated during the experiment. The possibility of instrumental data requires a highly theoretical conception of matter, grounded on extensive scientific judgments. Such a conception implicitly unites the specimen with a system of categories, relations, and hierarchies, which are necessary for the empirical investigation of nature (thesis (4')).

This analysis is not intended to demonstrate that rational science is grounded on Kant's entire architectonic system of *a priori* faculties. Nor does this discussion show that Kant's entire critical philosophy underlies modern experimentation. However, following Kant, the harmony that we discover in nature is actually a union of particularities of substance with universal principles, for the sake of empirical investigation. For Kant the possibility of experience requires a reciprocity between the so-called physicality of matter and the cognitive powers of mind, with judgment being the 'highest' faculty. The universal laws of understanding are just as necessary for formal nature as are the laws of motion regarding matter (*CJ*, 186). The mind is engaged in a '*Wechselspiel*' with nature's forces, a reciprocal game of a 'to and fro' between *actio* and *reactio* (E. Förster 1991, 44), uniting judgment with nature in the formal sense. The reciprocity between consciousness and nature underlies the possibility of empirical motion during a scientific experiment, in Kant's sense. Concerning modern experiments in chemistry, the instrument facilitates the mediation between the dynamical character of matter and the cognitive powers of the mind. The harmony between a system of matter and human understanding is guided by the principle of the purposiveness of nature, which functions as a precondition of scientific investigation of atomic processes.

Notes

1 Transcendental, *a priori*, and critique are closely related terms: transcendental (distinct from "transcendent" which means to go beyond the limits of experience) means our mode of knowing objects "in so far as this mode of knowledge is possible *a priori*" (*CPuR*, A12); *a priori* knowledge is that which is "absolutely independent of all experience" (*CPuR*, B3), which Kant applies in its strictest sense, searching for the *a priori* structures in consciousness (*CPuR*, A42/B60); critique becomes the method by which the sum total of these structures can be acquired (*CPuR*, A12/B26).

2 Kant's attempt to fix the ontological origin of the mind on *a priori* grounds has been a contentious issue in contemporary scholarship, but there is new interest in Kant's "naturalized epistemology", that is, apriority in consciousness made legitimate "because of the mind's active role at all levels of cognition" (P. Kitcher 1995).

[3] *Cf.* R. Butts 1984, 1986 and 1993; M. Friedman 1992; B. J. Edwards 1991; E. Förster 1991; P. Kitcher 1995.

[4] For a study of Kant's developing insights towards the Third Critique *cf.* Scherer 1995.

[5] M. Friedman (1992) argues that *CPuR* provides the schematism for the metaphysics for *MAdN*. Similarly, K. Westphal (1994) holds that Kant's "official" and "general" metaphysics is presented in the First Critique in which the "special" metaphysics of moving bodies in *MAdN* was a case *in concreto*. Kant's passages (*MAdN*, 478) seem to support such a reading.

[6] These four functions of thought (*CPuR*, B106) – quantity, quality, relation and modality – are extended to the four chapters of *MAdN*: "Phoronomy" treats motion as a pure quantity; "Dynamics" adds quality to the conception of matter; "Mechanics" explicates matter through its moving force; and "Phenomenology" shows how matter can be an object of experience.

[7] Judgment's dual function was Kant's rationale "for dividing the critique of judgment into that of *aesthetic* and that of *teleological* judgment" (*CJ*, 193). The objective-material function, "doctrinally" treated in *CPuR*, requires completion in Part 2 of *CJ*, "Critique of Teleological Judgment" while the subjective-formal function is analyzed in Part 1 of *CJ*, "Critique of Aesthetic Judgment".

[8] *Cf.* B. J. Edwards 1991; E. Förster 1991; M. Friedman 1992, Chapter 5; V. Mathieu 1991; B. Tuschling 1991.

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