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Rein Vihalemm

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Philosophy of Chemistry against Standard Scientific Realism and Anti-Realism

Rein Vihalemm

Institute of Philosophy and Semiotics,
University of Tartu (Estonia)

Résumé : Dans cet article, on suggère qu'un rôle central peut être assigné à la philosophie de la chimie dans la philosophie des sciences post-kuhnienne en général, et dans l'analyse du débat opposant le réalisme scientifique à l'anti-réalisme dans la philosophie des sciences standard. La philosophie des sciences construit la science comme une pratique plus que comme un réseau d'assertions. On soutient que le réalisme pratique permet d'éviter les défauts à la fois du réalisme scientifique standard et de l'anti-réalisme. On analyse un livre important publié récemment, B. Bensaude-Vincent's & J. Simon's *Chemistry — The Impure Science* [Bensaude-Vincent & Simon 2008], et on interprète la position des auteurs comme une sorte de réalisme pratique.

Abstract: In this paper, it is suggested that philosophy of chemistry can be seen as having quite a central role in the post-Kuhnian philosophy of science in general, and in analysing the scientific realism vs anti-realism debate in standard philosophy of science, in particular. The post-Kuhnian philosophy of science construes science as a practice rather than a network of statements. It is argued that practical realism can avoid the shortcomings of both standard scientific realism and anti-realism. An important recent book, B. Bensaude-Vincent's & J. Simon's *Chemistry — The Impure Science* [Bensaude-Vincent & Simon 2008] is analysed, and the position of the authors is interpreted as a kind of practical realism.

1 Introduction

At the 14th Congress of Logic, Methodology and Philosophy of Science, in Nancy, it happened for the first time in the history of the congresses of LMPS

that a special session was devoted to the methodological and philosophical issues of chemistry. In earlier times, it used to be taken for granted that chemistry should simply be classified as one of the physical sciences; this had been assumed in the programmes of the LMPs congresses as well. For instance, at the 12th Congress (held in Oviedo, in 2003) there was still reason to mention this outdated view [Vihalemm 2003b], although by that time philosophical analysis of chemistry had advanced at such a pace for a decade already (since the early 1990s) that the existence of philosophy of chemistry as a relatively autonomous discipline could not be doubted any more.

In the present paper, I would like to suggest that philosophy of chemistry can be seen as having a central role in the post-Kuhnian philosophy of science in general and, more specifically, in analysing the debate between scientific realism and anti-realism in standard philosophy of science. The post-Kuhnian philosophy of science construes science as a practice rather than a network of statements. I argue that practical realism can avoid the shortcomings of both standard scientific realism and anti-realism. Knowledge cannot be understood as a representation of the world which is independent of practice, and neither can practice be comprehended outside the framework of the real world.¹

2 Practical realism as an alternative to standard scientific realism and anti-realism

By standard scientific realism I mean the conception according to which:

1. there is a mind-independent world (reality) of observable and unobservable objects (the metaphysical-ontological aspect),
2. the central notion is truth as correspondence between scientific statements (theories) and reality (the semantic aspect),
3. it is possible to obtain knowledge about the mind-independent reality (the epistemological aspect),
4. truth is an essential aim of scientific inquiry (the methodological aspect).

To be an anti-realist in the debate about standard scientific realism means that at least one of these claims is rejected, and this is regarded—by the standard realists—as a rejection of (scientific) realism as such, though it may actually be a more specified understanding of realism instead of anti-realism—in the general sense of the term. Such is practical realism which avoids, as was already said, the shortcomings of both standard scientific realism and anti-realism.

1. In this paper, I assume the practical realist conception of philosophy of science I have developed in my previous papers [Vihalemm 2013, 2012, 2011c, 2001], [Vihalemm 2011b, 104–106], [Vihalemm 2005, 180–181].

Two main types of anti-realism are empiricist-instrumentalist anti-realism and social constructivist anti-realism. The latter—although it rejects the standard scientific realism—is entirely anti-realist only as its marginal outré variant. One must, however, agree with Joseph Rouse that despite the fact that “both the language and substance of ‘social construction’ was fading away”, there is still a need to explore the assumptions that allowed the debates “to be posed in the problematic terms of realism versus social constructivism” [Rouse 2002, 62–63].²

Standard scientific realism can be challenged owing to its abstract character, as being too remote from real practice. It is based on the aforementioned metaphysical-ontological presupposition, which raises the problem of the God’s Eye point of view (as it was called by H. Putnam [Putnam 1981, 49]). Although in the case of empiricist-instrumentalist anti-realism, or in the case of social constructivist anti-realism, which both try to avoid metaphysics—and also in the case of Putnam’s internal realism—there is no problem of the God’s Eye, their critique of realism is not acceptable, since they, too, operate in the context of traditional philosophy of science centered on language and logic, and are not founded on actual scientific practices; even if social constructivists “do attend to the material context of laboratory life [...], continuing a long tradition of text bias, they misdescribe the telos of science and technology exclusively in literary terms” [Baird 2004, 7].

Both standard scientific realism and empiricist-instrumentalist (or -constructivist) anti-realism—combined with the idea that progress in science means the constant discovering of new facts, and the interconnecting of these facts in some logical manner by creating theories, thereby acquiring more complete and exact knowledge of the world; so to say, approaching the truth, or its “surrogate”, the empirical adequacy, which is waiting “out there”—have lost in popularity in current philosophy of science, although not entirely disappeared. On empiricism we can say the same as on social constructivism:

Social constructivism and [standard scientific] realism are neither live options, nor comfortably dead letters. They are vampires, the philosophical undead that still haunt our concepts and interpretations of nature, culture and science. [Rouse 2002, 63]

The post-Kuhnian philosophy of science, which is practiced under different names (mainly as some kind of qualified realism, such as “critical”, “constructive”, “experimental”, “non-representative”, “referential” or “naturalistic” realism, but which sometimes may be a version of realism directly referring to practice, such as “pragmatic” or “practical realism”), in most cases tends to be practice-based in one sense or another. Therefore, it seems appropriate to speak about practical realist philosophy of science.

2. I am very sympathetic to the position of Rouse which is presented in the chapter 5 of his book [Rouse 1987, 127–165] under the title “Against Realism and Anti-Realism”.

In my earlier papers (see fn. 1), I have characterised *practical realism* by five main theses. I shall reiterate these theses here:

1. science does not represent the world “as it really is”, from a God’s Eye position;
2. the fact that the world is not accessible independently of theories—or, to be more precise, independently of paradigms (practices) developed by scientists—does not mean that Putnam’s internal realism [Putnam 1981, chap. 3] or “radical” social constructivism is acceptable;
3. theoretical activity is only one aspect of science; scientific research is a practical activity whose main form is scientific experiment; the latter, in its turn, takes place in the real world itself, being a purposeful, constructive, manipulative, and material interference with nature—interference, which is, in a crucial way, theory-guided;
4. science as practice is also a social-historical activity: among other things, this means that scientific practice includes a normative aspect which, in its turn, implies that the world actually accessible to science is not free of norms either;
5. though neither naïve nor metaphysical, it is certainly realism as it claims that what is “given” in the form of scientific practice is an aspect of the real world.

Or, to express this more succinctly, one could say that science as practice is a way of engaging with the world that allows the world to show how it can be identified in some of its possible “versions”. We are not “world makers”. Yet this is not to say that the world consists of self-identifying objects. Objects are identifiable only through practice—and, in principle, they are identifiable in a potentially infinite number of ways. In this sense, they are inexhaustible, having innumerable aspects and relating to the rest of the world in innumerable ways. As to practice, this is a human activity which consists in social-historical, critically purposeful, normative, constructive, material interference through interaction with nature and society, thus producing and reproducing the human world—culture—in nature. Knowledge, the knower, and the world which is known, are all formed in and through practice.

3 Thomas Kuhn as a pioneer of practice-based philosophy of science

Philosophy of science still debates Thomas Kuhn’s concept of *paradigm* [Kuhn 1970a] which is essentially a practice-based conception [Rouse 1987, chap. 2], [Rouse 1998, 2003]; cf. also [Hacking 1983], [Bird 2000]. I have argued that Kuhnian *paradigm* specified as a practice-based conception can be used as a criterion of science [Vihalemm 2000, 2004].

Alexander Bird has called pre-Kuhnian philosophy of science the “Old Rationalism”; he dubbed post-Kuhnian thinking the “New Paradigm”, to honour Kuhn’s most famous notion [Bird 2000, 3–7]. Kuhn himself spoke of “aprioristic rationalism” (instead of the “Old Rationalism”), meaning that philosophers of science used to proceed from a concept of rationality which had been borrowed from philosophy, not derived from actual science. The New Paradigm is primarily about taking the actual science seriously. It emphasises that science is not merely a logical, verbal and mathematical system; it is created by human agents, scientists, who belong to a wider community of specialists and operate in a specific system, or “world”, with its characteristic mental and material cultures—i.e., they operate in a “paradigm”. So, the New Paradigm basically means—as stressed by Joseph Rouse—that science is construed as a field of practices rather than a network of statements [Rouse 1987, 26], [Rouse 2003, 116].

It should be noted, however, that although it seems justified to speak about pre-Kuhnian *vs* post-Kuhnian history and philosophy of science, and to interpret Kuhn’s account of science in terms of paradigms as a practice-based approach, this does not mean that Kuhn himself elaborated such a viewpoint and is to be clearly associated with it. Among other things, Kuhn “is widely regarded as a social constructionist” [Wray 2010, 311]. One has to agree with Joseph Rouse’s claim that:

Thomas Kuhn’s *The Structure of Scientific Revolutions* has also been perhaps the most misunderstood. In particular, the depth of his criticism of the representationalist epistemology has often been overlooked. Kuhn has most commonly been read by philosophers as someone who ascribes a leading role to theory in science, who emphasises the noncumulative character of theory change, and who denies the possibility of nonneutral criteria for assessing the cognitive worth of such changes. [Rouse 1987, 26]

Also, it is well known that Kuhn himself wrote in “Reflections on my critics” [Kuhn 1970b, 231] that he “is tempted to posit the existence of two Thomas Kuhns. Kuhn₁ is the author of [...] *The Structure of Scientific Revolutions* [...] Kuhn₂ is the author of another book with the same title”. But, on the other hand, Joseph Rouse is right when he says that Kuhn’s ideas should be developed “further in the direction of an account of science as practice than he himself would be happy with” [Rouse 1987, 27]. I agree with Alexander Bird who states that:

in important respects Kuhn failed to break entirely with the preceding tradition. From the naturalistic perspective that has developed in “core philosophy” during the last two to three decades, which in due course spread to the philosophy of science, Kuhn’s views are shot through with commitments to the Cartesian and empiricist traditions he saw himself to be rejecting. Furthermore,

I argue that it is only *partial* rejection of positivism and empiricism that explains the radical appearance of the Kuhnian viewpoint—incommensurability, the conception of progress, the rejection of the concepts of truth and verisimilitude and, arguably the world change thesis, are consequences of positivist and empiricist views that Kuhn retained. [Bird 2000, x]

So, when we interpret Kuhn as a pioneer of practice-based philosophy of science and regard him as a critic of both standard scientific realism and empiricism (or perhaps even as a supporter of practical realism), it should be borne in mind that, although he laid the foundations of a new mode of thinking, he did not fully transcend the old tradition himself. As said, Kuhn's ideas should be developed further.

4 The role of chemistry in elaborating a practical realist philosophy of science

Chemistry is an excellent example for analysing science as a special kind of socio-historical, practical activity, and for elaborating a practical realist philosophy of science. In this context, it is worth pointing out that Kuhn's views evolved in close contact with chemistry and chemists (or chemists turned non-traditional philosophers of science, like James Conant, Leonard Nash, Michael Polanyi). It can be said that in many ways the "New Paradigm" in philosophy of science was founded on chemistry. When Roald Hoffmann asks, in the title of a paper published in *Synthese*, in 2007, "What might philosophy of science look like if chemists built it?" [Hoffmann 2007], one should better admit that in a certain sense chemistry *had* already greatly influenced the major change—the turn to practice—in the philosophy of science.

Somewhat paradoxically, although the discussion on scientific realism has always been a "major issue in the philosophy of science", and although it is clearly relevant for the science of chemistry as well (to quote, e.g., [Gieryn 2005, 150]: "A prototype for debates about scientific realism in twentieth century occurred at the end of the nineteenth century with questions about the reality of atoms and molecules"), until the 1990s "it is difficult to find references to chemistry in these debates [Van Brakel 2000, 20].

It is often assumed that chemistry was a typical positivist science as long as chemists used atomic and molecular models as merely fictions and denied any concern with their real existence. Even when they use notions such as molecular orbitals, chemists do not reify them and often claim that they are mere models or instrumental artifacts. [Bensaude-Vincent 2008, 45]

Since the early 1990s, however, philosophy of chemistry has been a rapidly developing branch of the philosophy of science, which has paid proper attention to the problem of scientific realism as well.

In the latter connection, and, more specifically, when discussing the relevance of philosophy of chemistry to the development of practical realist philosophy of science, which avoids the shortcomings of both standard scientific realism and anti-realism, I would like to refer first of all to some works, where science is analysed as practice (and chemistry is compared with physics), such as the books by Jaap van Brakel [Van Brakel 2000], Davis Baird [Baird 2004], Daniel Rothbart [Rothbart 2007] and, especially, a recent book by Bernadette Bensaude-Vincent & Jonathan Simon [Bensaude-Vincent & Simon 2008], and a collection of articles with the title *Stuff: The Nature of Chemical Substances* (edited by Klaus Ruthenberg & Jaap van Brakel [Ruthenberg & Van Brakel 2008]).

Proceeding from the aforementioned seemingly paradoxical point—that although scientific realism, with such central issues as the reality of atoms and molecules, should clearly be relevant to the science of chemistry as well, it had not really been addressed in the chemical context until the 1990s—we can say that this is where the specificity of chemistry, emphasised several times already, becomes evident: chemistry as a science remained outside the scope of philosophy for a long period of time, because the subject of chemistry is particular kinds of matter (i.e., substances, or stuffs) and their transformations, while in philosophy the fundamental ontology of matter has prevailed [Van Brakel 2000, 20, 71]. Joachim Schummer has written about the tensions between stuff and form philosophies (in that context) in [Schummer 2008], but also earlier. In van Brakel's book, we may read the following:

Schummer has argued that [...] there has been a subsequent *Entstofflichung* (“de-stuffing”) of philosophy, giving utter priority to form over substance or “stuff”: *Entstofflichung* of science (mechanical world picture) and of language [...]; knowledge of substance reduced to that of secondary properties or to Kant's *Ding-an-sich*.

Schummer suggests that chemistry is governed by an action-related conception of knowledge as distinct from the emphasis on formalisation and mathematisation of physics. This view doesn't merely emphasise the interactive aspects of the experimental side of science. The empirical praxis of making new things (new “stuffs”) is different from that of making careful measurements or carrying out “crucial” experiments. There is a greater affinity of chemistry to technology or art than to physics. [Van Brakel 2000, 71]

This is why chemistry has been regarded as an “impure” science. Bernadette Bensaude-Vincent & Jonathan Simon have published an excellent book with a characteristic title *Chemistry — The Impure Science* [Bensaude-Vincent &

Simon 2008]. The authors refer to the hybrid nature of chemistry, to “its constant mix of science and technology”:

[C]hemistry serves as the archetypical techno-science, unable to restrict itself to the high-ground of pure theory, but always engaged in productive practice. When we look back to past philosophers like Denis Diderot or Gaston Bachelard, we can see that the idea that there are two kinds of science—theoretical and practical—is nothing new. [...] Nevertheless, in the course of the last two centuries, the rise of modern physics has promoted pure theory over other forms of science, making it natural to characterize those that rest at the level of practice as impure if not degenerate. [Bensaude-Vincent & Simon 2008, 5]

However, they emphasize that it would be wrong to assume that chemistry lacks theories altogether. The authors state:

Indeed, we want to place special emphasis on this idea that theory and substance are co-produced by the chemist in the laboratory. [Bensaude-Vincent & Simon 2008, 6],

yet they also say, in another passage—referring to Kuhn’s notion of a “paradigm”—that at times “this theory is restricted to a community sharing a common scientific culture, there is no need to make this theory explicit” [Bensaude-Vincent & Simon 2008, 95].

Bensaude-Vincent & Simon find that “the characteristic philosophical stance of the chemist in the laboratory” is “operational realism” and that this should be seen “as a basis for rethinking the terms of philosophy of science” [Bensaude-Vincent & Simon 2008, 8]. I find that their approach can actually be regarded as a version of practical realism. On the one hand, the authors clearly criticise standard scientific realism “concerned with the reality behind the phenomena” and assuming “[...] that the aim of science is or at least should be to represent an external, independent reality” [Bensaude-Vincent & Simon 2008, 210]. Yet, on the other hand, what these authors call “operational realism” should not be identified with “instrumentalism”. This latter term used to apply to the anti-realist philosophical position which treats theories as conventional tools, constructs of the human mind “for calculations or classification without making any claims concerning the reality of the theoretical entities they deploy” [Bensaude-Vincent & Simon 2008, 206].

Chemists [...] rarely question the reality of the tools with which they do their chemical work, be they natural or artificial. [Bensaude-Vincent & Simon 2008, 206]

On the basis of chemistry—due to its practical-realistic nature—the drawbacks of not only traditional instrumentalism or empiricism but also those of social constructivism as a version of anti-realism are clearly seen. In chemistry

it is obvious that “action comes first, before conceptualization, nomenclature, or theory” [Bensaude-Vincent & Simon 2008, 6]. In chemistry there is so to speak intimate relationship between practical activity and realism [Bensaude-Vincent & Simon 2008, 209]. As it was already said above, actually only the marginal *outré* variant of social constructivism is entirely antirealist—“a kind of collective idealism” [Rouse 2002, 68]. However, the way social constructivism in general (i.e., not only its *outré* version) rejects the standard scientific realism (but not realism as such), when claiming that reality, nature or “the facts” are socially constructed, seems also not very clear and therefore is ultimately still often understood as a version of anti-realism. In contrast to the social constructivism, in the practical realist conception of practice it is recognised that

there *is* no such thing as “the social world” (*or* the “natural world”) except as reified abstractions from *the* world. The meanings, agency, institutions, or forms of life with which social constructivists would explain how nature becomes manifest to us are themselves senseless apart from those manifestations; they cannot be an independent explanans. [Rouse 2001, 192–193]

In practical realist philosophy, the subject—understood not as an abstract individual, but as a real socio-historical being—and its practical activity, recognised as a legitimate part of objective (material) reality, have objective characteristics as well. The subject is incorporated into reality as its specific component, and mind is no longer regarded as its only constituent property: literally, there are no incorporeal subjects. The impact of practice on reality is brought about not from “outside” but from “within” reality. It is the impact of one form of objective reality upon another—the impact of reality “in the form of activity” on reality “in the form of an object”.

The traditional model of knowledge acquisition treats subject and object as separate realities in their specific and independent existence, with their independent sets of characteristics. Activity is one subject’s properties and is, therefore, external to any object. Thus, the object is also external to the activity, and independent of it. The practice-based approach implies instead that practical activity has a status more fundamental than the status of individual object-things. An individual thing is identified as an existent object only through specifically defined activities within the context in which these objects appear as specific invariants. This is especially obvious in chemistry:

The assumptions underlying chemical practices do not concern things [as some kind of ready-made objects] such as barium sulphide. More precisely, this sort of “thingism” (*chosisme*) is not typical of chemists. Two major matters of concern more adequately their ontology: i) a concern for relations, and ii) a concern for action. [...] To be sure, chemists deal with individual substances, and pay attention to their molecular structures. However,

these things are only of interest to them in so far as they enter into relations with other units. [Bensaude-Vincent 2008, 50]³

Today it is also important to add:

When it comes to environmental and societal issues, definitions of chemical substances in terms of their molecular structure are not adequate. Rather it is what they do, or could do, to human tissues that is meaningful. For setting the standards of toxicity and correlative responsibility of industrial companies, distinctions between natural stable capacities and dispositions really matter. Chemical substances have to be clearly redefined by their intrinsic properties as well as by the dispositions they acquire in specific circumstances, or the affections they cause on human tissues or senses. [Bensaude-Vincent 2008, 52]

5 From chemistry to the theoretical model of science

I am happy to say that this view of chemistry as an “impure science”, or a science with dual or hybrid nature—not only in the sense of being between science and technology, but also as lying between “the two venerable scientific traditions of physics and natural history” [Bensaude-Vincent & Simon 2008, 212]—basically coincides with my own treatment of the dual character of chemistry, which I have been developing for quite a while now.

However, somewhat differently from Bensaude-Vincent’s & Simon’s view, I have proposed and developed—proceeding from the very same dual character of chemistry—also a conception of “pure science”, i.e., a conception of science in the specific, narrow sense of the term, namely, as an idealised physics-like science. This idealised science I describe by a theoretical model called *φ-science*, [Vihalemm 2011a,b, 2007, 2005, 2001], [Vihalemm 1999, 85–88]. *φ-Science* is constructive-hypothetico-deductive by its nature, in contrast to natural history, which is classifying-historico-descriptive.

In this connection, I would like to say that what I find especially valuable in Bensaude-Vincent’s & Simon’s philosophical analysis of chemistry is their

3. The problem of “thinghood” is actually quite central in realism/anti-realism discussions including when it concerns chemistry. One of the frequently used examples has been the discovery of the hormone TRH within biochemistry which has become known through a book by the supposed social constructivist anti-realists, Bruno Latour & Steve Woolgar [Latour & Woolgar 1979]. I have analysed this example referring to [Rouse 1987, chap. 5], [Hacking 1988], [Baird 2004] as an illustration of the practical realist approach to reality “in the form of activity” [Vihalemm 2012, sect. 4]. In this connection it is also interesting to refer to a so to speak negative case in the analysis of “thinghood”—the case of polywater [Van Brakel 2008, 150–154 and other references therein].

insistence that chemistry is of importance not only to philosophy of chemistry, but to philosophy of science in general:

It should, by now, be clear [...] that the popular image of chemistry as a superficial empirical science obliged to seek its philosophical foundations in other more fundamental science is quite inaccurate, if not philosophically defamatory. Whether this vision of chemistry is the deliberate construction of philosophers of science with a predilection for physics, or just results from the lack of attention paid to chemists' concepts and methods, it does great disservice to philosophy, depriving it of an interesting practice-based approach. [Bensaude-Vincent & Simon 2008, 209]

Due to its dual character, chemistry provides a good example for analysing the difference between physics-like science and natural history. Analysis of chemistry keeps us from simply identifying exact science with physics. Instead, it suggests that we should find out and explain philosophically why physics has obtained the status of the paradigm of science—as natural as this status may seem to be!—, and to reveal the premises and also the limits of this particular type of cognitive practice. I think that in a sense it all comes down to the simple fact that, in the actual historical practice—in the culture of the technological era and of the scientific world picture—physics has (after Galileo and Newton) obtained the aforementioned status of the paradigm of science so securely and, so to speak, naturally, that it blocks any need for critical reflection, for an analysis of why “physics” has become more or less synonymous with “real science”. It should be realised that theories, laws, concepts, etc., are not scientific simply because they are physical. It is obvious, for instance, that being a mathematically formulated physical theory or law is not itself the reason why this physical theory or law has gained the status of an embodiment of scientificity in general. So, the fact that chemistry is not a purely physical science, in the sense of not matching exactly the paradigm of “science proper”, makes its history a very clear example of the introduction of such a paradigm—which has to do with the constructing of scientific concepts and theories and with formulating scientific laws (yet bearing in mind that the terms “scientific” and “physical” are not synonyms)—into a field which was originally non-exact science. For instance, Mendeleev's periodic law, although not a mathematically formulated law of physics, is a real law of nature; it is exact in the same philosophical sense as are the laws of physics [Vihalemm 2003a, 2005], [Vihalemm 2011b, 101–103].

Mendeleev's periodic law has been one of the most characteristic and, at the same time, most puzzling examples in discussions of chemical laws and theories. This law seems to be essentially different in its nature from the exact laws of classical physics, the latter being usually regarded as a paradigm of science by philosophers. One should realise, however, that the periodic system of chemical elements was established by constructing an idealised system of idealised elements. Reference to the theoretical concept of a *chemical element* is

a fundamental idealisation substantiated by experimental chemistry—namely, a definite position in the periodical system based on the periodic law.

Comparing chemistry with physics, the philosophy and methodology of science can learn from the actual history of science what are the premises and limits of a science as exact (or ideal) science. Biology is not a good example because in this case, so to speak, the resistance of the material is too strong. Biology is clearly regarded as an altogether different type of cognitive practice, although, traditionally, it is also called “science” (but of its own type).

Of course, nowadays—and similarly to chemistry—biology has also, to some degree, become a discipline with a dual nature: molecular biology and genetics, for instance, are using ϕ -scientific models. Yet life cannot be constructed from scratch, investigation of living systems requires a classifying-historico-descriptive approach. By the way, physics seems to be acquiring a dual character as well, in a certain sense. The emergence of physical theories concerning self-organisation (as developed by Ilya Prigogine and others) indicates that physics itself as ϕ -science has certain premises, actual aims and limits [Vihalemm 2007a], [Vihalemm 2001, 195–196, 198].

6 In conclusion

Chemistry provides an excellent example for developing the conception of practical realism which is against standard scientific realism on the one hand, and against antirealism on the other. In chemistry, it proves to be so to speak natural that knowledge, the knower, and the world which is known, are all formed in and through practice as the legitimate aspects of objective (material) reality.

In their book with a characteristic title *Chemistry — The Impure Science* the authors Bernadette Bensaude-Vincent & Jonathan Simon refer to the hybrid nature of chemistry, to “its constant mix of science and technology” [Bensaude-Vincent & Simon 2008, 5]. The view of chemistry as “impure science”, or a science with dual or hybrid nature, not only in the sense of being between science and technology, but also as lying between “the two venerable scientific traditions of physics and natural history” [Bensaude-Vincent & Simon 2008, 212] largely coincides with this author’s treatment of the dual character of chemistry, and Bensaude-Vincent’s and Simon’s finding that “the characteristic philosophical stance of the chemist in the laboratory” is “operational realism” which should be seen “as a basis for rethinking the terms of philosophy of science” [Bensaude-Vincent & Simon 2008, 8], can actually be regarded as a version of practical realism.

Philosophical analysis of chemistry is important not only to philosophy of chemistry, but to philosophy of science in general,⁴ also including

4. See also reviews on the *Chemistry — The Impure Science* and the authors’ responses to them (“Book Symposium”) under the informative heading: “Ask not

developing—proceeding from the dual character of chemistry—a conception of “pure science”, i.e., a conception of science in the specific, narrow sense of the term, namely, as an idealised physics-like science, a theoretical model called *φ-science*.

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