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From the Dual Character of Chemistry to Practical Realism and Back Again: Philosophy of Science of Rein Vihalemm

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Abstract. The focus of the paper is on Rein Vihalemm's novel approach to science called practical realism. From the perspective of Vihalemm, science is not only theoretical but first and foremost a practical activity. This kind of approach puts chemistry rather than physics into the position of a typical science as chemistry has a dual character resting on both constructive-hypothetico-deductive (ϕ-science) and classifying-historico-descriptive (non-ϕ-science) types of cognition. Chemists deal with finding out the laws of nature like the physicists. However, in addition to this they deal with substances or stuff that is rather an activity typical to natural history. The analysis of the dual character of chemistry brings about the need to analyse philosophically the reasons why physics has held the position of the only science proper so far. The comparative analysis of physics and chemistry at the basis of practical realism suggests that it is chemistry rather than physics that should hold a special position among sciences. Perhaps we should exchange ϕ-science for χ-science.
Keywords: chemistry and philosophy of science, ϕ-science, physics and philosophy of science, practical realism, Rein Vihalemm

Nuo dvejopos chemijos prigimties prie praktinio realizmo ir atgalios: R. Vihalemmo mokslo filosofija

Santrauka. Straipsnyje susitelkiama į vadinamąjį praktinį realizmą – naujovišką Reino Vihalemmo prieigą prie mokslo. Pagal Vihalemmą, mokslas nėra tik teorinis, bet pirmiausia ir daugiausia – praktinis užsiėmimas. Tokia traktuotė vietoje fizikos kaip tipinį mokslą iškelia chemiją, nes ji esanti dvejopo pobūdžio: konstruktyvus-hipotetinis-deduktyvus mokslas (ϕ mokslas) ir tuo pat metu – klasifikacinis-istorinis-deskriptyvus mokslas (ne ϕ mokslas). Chemikai aiškinasi gamtos dėsnius taip pat kaip ir fizikai. Vis dėlto kartu jie dirba ir su medžiagomis, su konkrečiais daiktais, o ši veikla yra labiau gamtos istorijos užsiėmimas. Chemijos kaip dvejopo mokslo analizė iškelia poreikį filosofiškai išaiškinti priežastis, dėl kurių fizika iki šiol laikoma vieninteliu tikruoju mokslu. Praktiniu realizmu grindžiama lyginamoji fizikos ir chemijos mokslų analizė rodo, kad veikiau chemija nei fizika turėtų užimti ypatingą vietą tarp mokslų; galbūt ϕ mokslas turėtų pakeisti χ mokslą.
Pagrindiniai žodžiai: chemija ir mokslo filosofija, ϕ mokslas, fizika ir mokslo filosofija, praktinis realizmas, Reinas Vihalemmas

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The leading Estonian philosopher of science Rein Vihalemm was the Editorial Board member of *Problemos* for many years. In summer of 2015, Vihalemm died in a tragic boating accident at the age of 76. Vihalemm was a chemist by his background but changed to philosophy of science soon after graduating from the University of Tartu with a diploma in chemistry. However, Vihalemm started his career as a historian of chemistry first by publishing the book "A Story of a Science" (Vihalemm 1981). The book has recently been translated into English and published as a special edition of the journal *Acta Baltica Historiae et Philosophiae Scientiarum* (Vihalemm 2019).

In a way, one might claim that philosophy of chemistry started from this book. In addition to telling the main facts and explaining the main theories of chemistry in the historical order, Vihalemm offers a deep analysis about why we cannot consider alchemy a science but rather a cultural phenomenon of its age and how does it differ from chemistry as a science. Our suggestion is that it is exactly this point where Vihalemm developed the very basic ideas of his later philosophy of science and of chemistry.

In the current paper, we shall address one by one the main original contributions of Vihalemm to philosophy. The first one was a novel solution of the most fundamental problem of the philosophy of science – the problem of demarcation. The next one would be finding out and describing the dual nature chemistry. The most important contribution of Vihalemm, however, is the new account of science that he called practical realism. Unfortunately, an untimely death did not allow him to fully develop this interesting approach. However, Vihalemm managed to show that practical realism might serve as a basis for changing the course of the whole philosophy of science, challenging the position of physics as the only science proper (Vihalemm 2015).

The Problem of Demarcation and the Model of Science

The background of the problem of demarcation is common knowledge in philosophy of science as well as its classical solutions, verification and falsification. Both of them work for distinguishing science from non-science. However, these solutions raise numerous problems that are again well known and widely discussed in the philosophy of science. All this motivated Vihalemm to deal with the problem of demarcation on his own and to present an original solution.

Vihalemm took off from distinguishing between two types of cognition, constructive-hypothetico-deductive and classifying-historico-descriptive (Vihalemm 2001). Science, in the narrow sense of the term, is the cognitive activity based on the constructive-hypothetico-deductive type of cognition. The concept of hypothetico-deductive has been in use for a long time. William Whewell is normally credited as its founder, although the case is not conclusively clear. Where 'constructive' comes from and what does it mean? According to Vihalemm, the scientist does not have access to the world as it is from the so-called God's-eye point of view. She has to construct the research object for herself from the basis of her own cognitive capacities. This sounds like Kantian apriorism and perhaps is really close to that classical view in philosophy. However, there is still a big

difference with Kant's position. It is not just human cognition, which is at work during doing research. Reality is there as well and plays its direct role. The researcher has no access to reality as it is but is still in contact with it. The researcher cannot construct any kind of research object from her own deliberation because reality will resist.

If we raise the question what kind of really existing science is of the constructive-hypothetico-deductive type, then would the response be physics? At least it is the closest to the type. However, perhaps just classical mechanics falls for more or less fully under the category. Physics is a living and developing science and therefore is not fit for playing the role of the model for the whole science. This is the reason why Vihalemm created the ideal model of science that he called ϕ-science. The latter is a cognitive activity that relies fully on the constructive-hypothetico-deductive type of cognition. It adheres to the Galilean methodology. The major parts of the latter are formulating a testable hypothesis about a constructed research object or a relation, testing the hypothesis by means of reproducible experiments and expressing the result in the language of mathematics.

The key term in this classical approach to the methodology of science is reversibility. Time does not have any meaning in classical physics and actually, not even in the non-classical one. Irreversibility as an objective phenomenon comes in only in the post-non-classical science as Stepin (2005) called it. By this term, Stepin mostly means the work of Ilya Prigogine on dissipative structures (Prigogine, Stengers 1984, 1997). However, synergetics initiated by Hermann Haken as well as bifurcation theory, chaos theory, etc. also fall under this category. Reversibility does not fit in with these approaches. Let us stress that the irreversibility introduced here is an objective one not the subjective irreversibility we all experience through our senses on a daily basis. The objective nature of irreversibility in the approach of Ilya Prigogine has been explained, for instance, in a paper by Näpinen and Müürsepp (2002).

From our current perspective, it is important to notice that post-non-classical physics is not fully a ϕ-science any longer. This is why Vihalemm could not refer just to physics as the ideal model of science. The recent developments in physics indicate that its nature is changing and it does not adhere to the model in each and every respect and detail. By the same reason, Stepin could not just refer to Prigogine or his methodology of self-organization but had to coin the term 'post-non-classical science'. There are other approaches of the same type as well, not just Prigogine's. Let us also point out that Ilya Prigogine was also a chemist at least as much as he was a physicist. The Nobel prize was awarded to him in chemistry. The disciplinary boundaries between physics and chemistry are blurred in his work.

By all evidence, the model of ϕ-science makes sense and works. Science that is based on the classifying-historico-descriptive type of cognition Vihalemm calls non-ϕ-science. Everything that has classically been called natural history falls under this category. The broad understanding of science includes both ϕ-science and non-ϕ-science. In addition, there is still social science of course. There is no normative assessment of different sciences and different types of cognition here. Just the major differences have been pointed out. We cannot say that knowledge provided by physics is necessarily better in every respect

rather than, for example, geographical or sociological knowledge. However, knowledge provided by ϕ-science is the most exact and objective one. Here, the subjective role of the researcher is pushed to the minimum. However, it is still never missing as we'll see below in the context of practical realism.

The Dual Character of Chemistry

We saw in the previous chapter that classical physics adheres to the model of ϕ-science but even physics in its post-non-classical version does not do so fully. However, what about chemistry? Should it be considered a ϕ-science or rather a non-ϕ-science? The response to this question has been developed by Vihalemm in many of his research papers (1999, 2001, 2003a, 2003b, 2004, 2005, 2007a, 2007b, 2011a, 2016). Vihalemm offered solid ground for considering chemistry a science of dual character. The list of Vihalemm's publications on the topic given here is not exhaustive. He has addressed it in several other works as well but there the issue of the dual character of chemistry has not occupied the centre ground. Some other authors have discussed the same or similar issues concerning chemistry as well (Bensaude-Vincent, Simon 2008), (Müürsepp 2004).

In order to follow the thread, we have to introduce another notion – physics-like science. It can be taken almost as a synonym to ϕ-science. However, we must keep in mind that there may be physics-like science, dealing with self-organization for instance, that is not purely ϕ-science.

What does the dual character of chemistry actually mean? Based on what has been said above, it is perhaps obvious that the idea has to be that chemistry is partly a ϕ-science and partly a non-ϕ-science. Chemistry is physics-like to some extent beyond any reasonable doubt. Just like physics, chemistry also aims at finding out regulations in nature that can be called laws. However, this is not what the whole chemistry is about. Chemistry also deals with substance or stuff. This raises the question whether the physics-like part of chemistry is not just physics-like but actually belongs to physics. We are going to show, however, that this would not be an appropriate interpretation of chemistry.

Let us take a look at the most famous law of chemistry, the law of periodicity of Dmitri Mendeleev. We cannot possibly do without this because the year 2019 has been proclaimed official year of the periodic table by UNESCO commemorating the one hundred and fifty years anniversary of Mendeleev's discovery. The discovery of the periodicity law is a very good example of applying the constructive-hypothetico-deductive type of cognition. The law is about the chemical elements. However, what is a chemical element after all. Vihalemm puts it like this: "[a] fundamental idealisation substantiated by experimental chemistry – namely, a definite position in the periodical system based on the periodic law" (Vihalemm 2015: 111). Thus, the periodicity law rests on the constructed objects called chemical elements that have been specified with the help of the law itself. Still, the result is not anything like an arbitrary construction of the human mind but a real regularity of nature. The law rests on the constructive activity combined with experimental support. It expresses a real objective relationship. However, there is no need for the mathematical expression of the result except

for giving the number of the atomic weight. The periodicity law is not a law of physics. It is a law of chemistry. The story of the law of periodicity shows that part of chemistry is a ϕ-science type of activity. It is physics-like but it cannot be reduced to physics.

It is obvious, however, that looking for the laws of nature is not the only activity of chemists. They are also dealing with substances or stuff. This is definitely not a constructive-hypothetico-deductive but a classifying-historico-descriptive type of cognitive activity. More than that, the non-ϕ-science side of chemistry is a clearly practical, results oriented scientific activity. However, the case of chemistry is even more interesting. We need not look at the ϕ-science and non-ϕ-science side of chemistry as done separately and at different times. They can co-exist in perfect cooperation. Bensaude-Vincent and Simon observe: "Indeed, we want to place special emphasis on this idea that theory and substance are co-produced by the chemist in the laboratory" (2008: 6). In a way, even the periodicity law was produced in a laboratory. Chemistry is really a practical science (Müürsepp 2016). There is still more. Based on its practical nature, chemistry can also be called a technical science. Again, Bensaude-Vincent and Simon help us to understand the idea: "[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" (2008: 5). If Vihalemm's understanding of chemistry tends to separate it into two parts then the approach of Bensaude-Vincent and Simon keeps chemistry together but emphasizes its impure character. However, the impurity of Bensaude-Vincent and Simon and the dual character pointed out by Vihalemm are the same thing in essence. This is the position of Vihalemm himself as well (2015).

Under the strong influence of the dual character of chemistry the authors of both approaches have called their general positions different kind of realisms. In the next section, we focus at Vihalemm's practical realism but pay some attention to the operational realism of Bensaude-Vincent and Simon as well.

Practical Realism

As a continuation to presenting an original solution of the problem of demarcation and explaining the dual character of chemistry, Vihalemm worked out his own general account of science that he called practical realism. This happened roughly at the beginning of the second decade of this century. Let us first give the main theses of practical realism and then explain the background in more detail:

"1. Science does not represent the world "as it really is" from a god's-eye point of view. Naïve realism and metaphysical realism have assumed the god's-eye point of view, or the possibility of one-to-one representation of reality, as an ideal to be pursued in scientific theories, or even as a true picture in the sciences.

2. The fact that the world is not accessible independently of scientific theories – or, to be more precise, paradigms (practices) – does not mean that Putnam's internal realism or "radical" social constructivism is acceptable.
3. Theoretical activity is only one aspect of science; scientific research is a practical activity and its main form is the scientific experiment that takes place in the real world, being a purposeful and critical theory-guided constructive, as well as manipulative, material interference with nature.
4. Science as practice is also a social-historical activity which means, amongst other things, that scientific practice includes a normative aspect, too. That means, in turn, that the world, as it is accessible to science, is not free from 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, perhaps more precisely, science as practice is a way in which we are engaged with the world" (Lõhkivi, Vihalemm 2012: 3).

This is a somewhat elaborate version of the theses. Probably the first version of the five theses was given by Vihalemm one year earlier (2011b). Later on he has elaborated the account in several other papers (Vihalemm 2012, 2013, 2015). Practical realism has definitely been mentioned in some more publications by Vihalemm. The first paper about practical realism (Vihalemm 2011b) is especially valuable because there he points out all the major influences he had experienced that have motivated him to present his own account, called practical realism. Let us take a look in a more or less historical order.

There is no news that Vihalemm, as all academic people of his age in the Baltics, received his education in the academic milieu of the Soviet Union. Although philosophy in the USSR was not homogenous, it is well known that from the official point of view Marxism-Leninism was the only correct philosophy in the country. There were philosophical communities, like the Moscow logical circle, that did not belong to Marxism strictly speaking. However, even such rare exceptions were under the influence of Marxism. There were individuals in the Soviet Union and the satellite states who did not take Marxism seriously and contributed directly to the international scene of the philosophy of science.

Still, every individual who was active in philosophy in the USSR had at least to pretend to be a Marxist. In Estonia, however, the philosophers developed something that later on has obtained the name 'foreword Marxism'. As the term suggests, the approach meant that Marxist views supported with relevant quotes form Marx, Engels and Lenin were presented just in the forewords of philosophical texts and later on, the authors often diverged quite far from Marxist orthodoxy. The tactics worked because the censors rarely cared to read more of philosophy texts than just the forewords. The philosophers of science, however, even managed to take their own advantage from the requirement to base their considerations on Marxism (Mets 2019). First of all this concerned Karl Marx's conception of practice. The conception need not be looked at in the context of stimulating social change although that was probably Marx's predominant idea. Actually, his considerations on practice have a much wider significance.

The major source of Marx's approach to the understanding of practice are his theses on Feuerbach, especially the first two ones. In the first thesis Marx writes: "The main defect of all hitherto-existing materialism—that of Feuerbach included—is that the Object [*der Gegenstand*], actuality, sensuousness, are conceived only in the form of the object [*Objekts*], or of contemplation [*Anschauung*], but not as human sensuous activity, practice [*Praxis*], not subjectively. Hence it happened that the active side, in opposition to materialism, was developed by idealism—but only abstractly, since, of course, idealism does not know real, sensuous activity as such. Feuerbach wants sensuous objects [*Objekte*], differentiated from thought-objects, but he does not conceive human activity itself as objective [*gegenständliche*] activity. In The Essence of Christianity [*Das Wesen des Christenthums*], he therefore regards the theoretical attitude as the only genuinely human attitude, while practice is conceived and defined only in its dirty-Jewish form of appearance [*Erscheinungsform*]. Hence, he does not grasp the significance of 'revolutionary', of 'practical-critical', activity" (Marx 1845). We must not be disturbed by the reference to the revolutionary here. Although Marx probably understood it from the position of the social change, the revolutionary can well be taken from the point of view of understanding science and the philosophy of science as practice rather than just a sterile conceptual analysis of scientific terms and their connecting relations. This is how the foreword Marxists took the point.

Marx's position on practice is even more clearly there in the second thesis: "The question whether objective truth can be attributed to human thinking is not a question of theory but is a practical question. Man must prove the truth, *i.e.*, the reality and power, the this-sidedness [*Diesseitigkeit*] of his thinking, in practice. The dispute over the reality or non-reality of thinking which is isolated from practice is a purely scholastic question" (Marx 1845). Again, we must admit that the quote has a deep meaning in the philosophical understanding of science. Overwhelmingly theoretical, even scholastic, attitude has been dominating in science way too long. The reason for this has probably been the model role of physics and the praising of the theoretical side of it that actually started with Galileo already. Shifting the focus towards chemistry might be a quite healthy tendency. Vihalemm has repeatedly emphasized being influenced by Marx's treatment of practice, concerning the understanding of the development of science of course. There is nothing to be surprised about if we remember that Vihalemm is a chemist by his basic qualification.

It is quite obvious that this is chemistry rather than physics that serves as the model science from the point of view of practical realism, although Vihalemm has never put it in such a straightforward way. However, let us see, which other approaches that have influenced Vihalemm on his journey towards practical realism. At least as strong influence as the Marxist one comes from the practical approach to the philosophy of science of Joseph Rouse. A nice brief explanation of Rouse's approach appears in his own works: "[t]he question is not how we get from a linguistic representation of the world to the world represented. We are already engaged with the world in practical activity, and the world simply is what we are involved with. The question of access to the world, to which the appeal to observation was a response, never arises. The important categories for characterizing the ways the world becomes manifest to us are therefore not the observable and

unobservable. We must ask instead about what is available to be used, what we have to take account of in using it, and what we are aiming toward as a goal" (Rouse 1987: 143). In addition to the stress on practice, Rouse is emphasizing the lack of the need for any metaphysics in science. Vihalemm is aiming at the same attitude with his practical realism. This makes his position controversial. We'll get back to this issue below.

There are other thinkers, whose ideas influenced the views of Vihalemm. First, there is 'the pragmatic realism' developed by Sami Pihlström (Pihlström 1996, 2008: 26-69). Pihlström has shown that pragmatist philosophy of science can be interpreted as a version of realism. There is more Finnish influence coming from perhaps the most well-known and influential living philosopher of science in Finland Ilkka Niiniluoto. His critical scientific realism (Niiniluoto 1999) has made an impact on Vihalemm as he admits.

Now comes the controversy. It is connected to the approach to the understanding of science of Nicholas Maxwell. Large part of Maxwell's life work has been dedicated to the criticism of the commonly accepted approach to science that he calls standard empiricism (SE) and promotion of a different kind of approach that Maxwell calls aim-oriented empiricism (AOE). The core of the problem is that, according to Maxwell, scientists have firmly adopted the approach that no statement should be included into science independently of evidence. In reality, however, scientists constantly make metaphysical assumptions. They presume that the universe is comprehensible, prefer unified theories over disunified ones and simple theories over more complicated ones, even if there are infinitely many disunified and/or complicated rival theories that are empirically more successful. Thus, metaphysical assumptions are actually inherent components of science and this has to be recognized. This recognition would mean changing from SE to AOE. Maxwell has presented his criticism of SE and promotion of AOE in very many publications. Just two years ago, however, the most systematic treatment appeared (Maxwell 2017).

The controversy is connected to the acknowledgement of the role of metaphysics in science. Vihalemm has pointed out that Maxwell's criticism of SE meets with approval in the context of practical realism (2011b). On the other hand, however, Vihalemm does not recognize the need for the metaphysical assumptions in science. This attitude of Vihalemm stretches back quite far. Vihalemm has adhered to the naturalist approach to philosophy of science proclaiming philosophy of science without philosophy (1993). The same tendency is clearly visible in the five theses of practical realism. There is a strong emphasis on the normative aspect of science there but there is no place for metaphysics. The not reachable part of the world is not the metaphysical unobservable for Vihalemm. The point should rather be understood in Joseph Rouse's way as being in contact with reality in a certain way, the only possible one according to Rouse and Vihalemm.

One clearly pointed out issue in the five theses of practical realism asks for clarification. It is the reference to the internal realism of Hilary Putnam. Just like Vihalemm, Putnam also denied the God's-eye view capacity to the human observer. That is why he could not agree with metaphysical realism and proposed his own approach. However, there is an important question here. In what respect is practical realism different from internal realism? It has to be different because internal realism is not even acceptable for

Vihalemm. Putnam explains metaphysical realism as follows: "What the metaphysical realist holds is that we can think and talk about things as they are, independently of our minds, and that we can do this by virtue of a "correspondence" relation between the terms in our language and some sorts of mind-independent entities" (Putnam 1982: 141-167). According to Putnam, such kind of correspondence cannot be substantiated. However, what does internal realism provide in replacement? The world is independent from the human mind but the structure of the world is still prescribed by the human mind in a way. A quite Kantian position. We cannot say that practical realism is free of Kantianism. However, there is really no requirement that the human mind has to prescribe something to the world. The researcher just exercises contact with the world (remember Rouse again). Here, information that the researcher receives from reality is structured according to the sensual capacity we humans have. Kant comes in at this point. The 'prescription theory' makes internal realism something else rather than realism altogether, a kind of constructivism.

Practical realism also proclaims social constructivism unacceptable. The corresponding explanation by Vihalemm is clear and straightforward. Social constructivism, at least in its radical form, is self-refuting since social constructivist views are also constructions (Lõhkivi, Vihalemm 2012: 3). In addition, social constructivism contradicts common sense. We cannot construct anything we like as reality resists (Lõhkivi, Vihalemm 2012: 3).

Quite obviously, it is chemistry, rather than physics that works best as a model field for a practical realist account of science. By this reason, accepting practical realism might even shift the focus of the whole philosophy of science. For more than a century, the latter was undisputedly physics centred. Chemistry very seldom achieved any special mention beside physics. It was rather taken as something like a younger brother of physics, as the same type of science as physics, just a bit underdeveloped as compared to the 'big brother'. The practical realist approach enables to strengthen the view that chemistry is definitely a science in its own right. More than that, chemistry need not be analysed taking physics as a model but a philosopher of science might act *vice versa* as well. The historically special position of physics among sciences may become better analysable on the background of physics' relationship to chemistry.

Chemistry provides us with a good basis for analysing the relationship between physics-like science and natural history. It is interesting that the existence of chemistry alone prevents us from identifying exact science with physics. We cannot take the position of physics as the only science proper for granted any longer. We cannot exclude the option that this analysis may even dethrone physics from its seemingly secure core position among all versions of science.

The latter brings us into contact with one of the basic philosophical questions about social science. Is it reasonable to try to keep physics as a model of science even for social science? It looks as so far philosophers have rather been looking for a yes-no solution here. However, it may be that a dual type of approach to social science is more reasonable. Parts of social science (in the broad sense) can make good use of mathematics, for instance. Therefore, we could even speak about some remote physics-likeness here. However, any kind of social science cannot come close to the model of ϕ-science. Social science is not

natural history either. It rather connects to social history. Thus, mainly social science could probably be a kind of social philosophy of a practical type, attempting to figure out the major problems human societies as well as individuals are facing and suggesting solutions where and when possible. A modified practical realism might work for social science as well, although Vihalemm himself would perhaps not agree with this.

The history of chemistry is a good example how a cognitive approach to nature evolved into science (in the modern sense). Physics, in the form of classical mechanics, was born parallel to this evolvement. Modern physics started as pure science and therefore it initially became the model. Or rather, the methods of classical mechanics became the role model for the whole science. However, non-classical and especially post-non-classical physics are not really entirely pure exact science in the classical sense. One just needs to consider the changing role of the experiment, the problems with reproducibility (Müürsepp 2012) in order to see this. Interestingly, even in the context of the experiment, chemistry takes up a significant, perhaps even the leading position. Chemical experiments expose better the need to drop the requirement of reproducibility and the reversibility of time even in exact science. Normally, different chemical experiments directed at creating new stuff don't develop in the same way. Similarity can be detected just on the level of patterns.

Vihalemm's understanding of the experiment has been nicely presented in the main theses of practical realism. It is a theory guided manipulative material interference with nature. We cannot have experimental research where such kind of manipulative material interference is not possible. Manipulation means constructing. Therefore, there cannot be a non-experimental ϕ-science and not even a non-experimental science of dual character in the sense of chemistry.

However, let us still take a look into the character of biology. We have to admit that contemporary biology provides us with a similar situation like chemistry to some extent at least, especially as far as molecular biology and genetics are concerned. That side of biology has the essence of a ϕ-science. Thus, strictly speaking, biology is also a science of a dual character. It will be very interesting to follow from the philosophical point of view the forthcoming developments in biology. At this point, biology does not really compare with chemistry yet concerning its impact as a science of dual character. Vihalemm explains that in biology the resistance of the material is too strong (Vihalemm 2015: 111). The material here would be living matter. Dealing with life, biology cannot really obtain the constructive character similar to physics and chemistry. It has to remain based on the classifying-historico-descriptive type of cognition, to remain a non-ϕ-science. However, there may be the tendency to become a science that is closer to chemistry. After all, there is biochemistry that deserves also special philosophical attention. Let that remain, however, a topic for further analyses.

Back to the Special Position of Chemistry, Making it even more Special

As we know already, there are other thinkers in addition to Vihalemm, who have noticed the dual character of chemistry. Bernadette Bensaude-Vincent and Jonathan Simon, for instance, have interesting observations. They call chemistry an archetypal techno-science

because it cannot restrict itself to pure theory but always engages with productive practice (Bensaude-Vincent, Simon 2008: 5). At first, this seems a quite different dualism compared to Vihalemm's. However, Bensaude-Vincent and Simon also point out an aspect of chemistry that supports the practical realist understanding of science. The authors emphasise that throughout the last couple of centuries, physics has promoted pure theory over other forms of science (Bensaude-Vincent, Simon 2008: 5). Actually, it's probably even longer than that as we hinted above. As physics had the position of the role model, anything practical concerning science became an indication of being away from the ideal. Research in chemistry, however, reminds us about the practical side of science. We know already that Bensaude-Vincent and Simon observed that in chemistry theory and substance are co-produced by the chemist in the laboratory (Bensaude-Vincent, Simon 2008, 6). This idea takes Bensaude-Vincent and Simon close to practical realism and other ideas of Vihalemm. The produced substance (or stuff) is not constructed. It is a real product of chemistry and dealing with it bases on the classifying-historico-descriptive type of cognition.

In order to specify the position of their account in philosophy of science, Bensaude-Vincent and Simon introduce the term 'operational realism'. They emphasise that the term was coined under the influence of the chemists' activities in the laboratory and add an ambitious belief that the basics of the philosophy of science will be rethought under the influence of their approach (Bensaude-Vincent, Simon 2008: 8). They mean that chemistry looks well suited to overtake the position of the most typical science.

There is nothing surprising that chemists mostly work in the laboratory and therefore chemistry is a practical science almost by definition. However, it takes more than this to explain the special practical-operational status of chemistry that makes it a technical science. The ϕ-science non-ϕ-science dichotomy may look similar to the theoretical practical one. This is how Bensaude-Vincent and Simon see the hybrid nature of chemistry as they sometimes call it. For Bensaude-Vincent and Simon chemistry is impure exactly because of its tendency to look for practical results and solutions or applications. Here is the point of connection with technology and engineering science. The latter always aims at practical applications. Bensaude-Vincent and Simon see the same driving force in chemistry, although just in some part of it. Chemistry is a constant mix of science and technology that they understand along the lines of the theoretical practical mix.

As mentioned above, Bensaude-Vincent and Simon call their approach 'operational realism'. It is interesting to observe, what is the relationship between practical realism of Vihalemm and operational realism of Bensaude-Vincent and Simon? The main theses of practical realism are clearly in place (see above). Operational realism has not been spelled out in such a plain manner. There may be the question about the realist nature of practical realism. However, this question is more obvious in the case of operational realism. In the case of practical realism there is a similarity with the internal realism of Hilary Putnam. However, this kind of similarity makes practical realism even more a realism in a way. Operational realism, on the other hand, can be confused with instrumentalism. Still, Vihalemm thinks that there is a clear difference. Instrumentalism traditionally applies to

anti-realist philosophical positions, which treat theories as conventional tools, constructs of the human mind (Vihalemm 2015, 108). Chemists, however, normally don't question the reality of their tools. Bensaude-Vincent and Simon call this an intimate relationship between practical activity and realism (2008: 209). Thus, Bensaude-Vincent and Simon are almost saying themselves that their approach is actually practical realism.

Perhaps it is not fully appropriate to call chemistry a technical science, at least in the direct sense of the term, but the methodological similarity of chemistry to engineering science in general terms even strengthens the claim of chemistry to become a science of very special interest to the philosophy of science. It connects physics-like science with not physics-like natural science in an interesting way and enables to add engineering science into the picture. These considerations might mean that we should develop a replacement for the model of ϕ-science and call it χ-science instead. At this point however, the latter conception is obviously underdeveloped in order to become fully established. Remembering some conference discussions and personal conversations with Vihalemm, we must admit that the idea of χ-science did not become acceptable to him.

Conclusion

In the current paper, we have followed Vihalemm in his footsteps throughout his career from his early book about the history of chemistry through the two understandings of human cognition and the conception of ϕ-science to the exposition and short analysis of the original account of science called practical realism. In addition to reiterating the main ideas of Vihalemm, we have tried to clarify some more complicated issues, especially in the context of practical realism. The core of the whole paper, however, is the special character of chemistry that was masterfully exposed by Vihalemm throughout his career. Our hope is that the paper gives more weight to the idea that chemistry is a special kind of science due to its clearly exposed dual character. Thus, chemistry is definitely of special interest to the philosophers of science and chemistry. In addition, clarifying the essence of chemistry will help to analyse philosophically the long lasting understanding of physics as the only science proper and may lay foundations to considerable changes in the whole philosophy of science.

References

Bensaude-Vincent, B., Simon, J., 2008. *Chemistry – The Impure Science*. London: Imperial College Press.

Lõhkivi, E., Vihalemm, R. 2012., Guest editorial. Philosophy of science and practical realism. *Studia Philosofica Estonica* 5(2): 1–6. https://doi.org/10.12697/spe.2012.5.2.01

Marx, K., 1845. Theses on Feuerbach, http://www.marxists.org/archive/marx/works/1845/theses/index.htm Accessed 17 March 2019.

Maxwell, N., 2017. *Understanding Scientific Progress. Aim-Oriented Empiricism.* St. Paul, Minnesota: Paragon House. https://doi.org/10.1007/s11191-019-00072-y

Mets, A., 2019. A Philosophical Critique of the Distinction of Representational and Pragmatic Measurements on the Example of the Periodic System of Chemical Elements. *Foundations of Science* 24: 73–93. https://doi.org/10.1007/s10699-018-9567-x.

Müürsepp, P., 2004. Chemistry as an independent science. *Studia Philosophica* (IV)40: 131–138.

Müürsepp, P., 2012. The changing role of scientific experiment. *Studia Philosophica Estonica*, 5(2): 152–166. https://doi.org/10.12697/spe.2012.5.2.10

Müürsepp, P., 2016. Chemistry as a practical science (Edward Caldin revisited). *Foundations of Chemistry* 18(3): 213–223. https://doi.org/10.1007/s10698-016-9257-0

Niiniluoto, I., 1999. *Critical Scientific Realism.* New York: Oxford University Press.

Näpinen, L., Müürsepp, P., 2002. The concept of chaos in contemporary science: on Jean Bricmont's critique of Ilya Prigogine's ideas. *Foundations of Science* 7: 465–479. https://doi.org/10.1023/a:1020729714449

Pihlström, S., 1996. Structuring the World: The Issue of Realism and the Nature of Ontological Problems in Classical and Contemporary Pragmatism. *Societas Philosophica Fennica*.

Pihlström, S., 2008. How (Not) to Write the History of Pragmatist Philosophy of Science *Perspectives on Science* 16(1): 26–69. https://doi.org/10.1162/posc.2008.16.1.26

Prigogine, I., Stengers, I., 1984. *Order Out of Chaos: Man's New Dialogue With Nature*. Flamingo.

Prigogine, I., Stengers, I., 1997. *The End of Certainty: Time, Chaos and New Laws of Nature*. New York: Free Press.

Putnam, H., 1982. Why There Isn't a Ready-Made World. *Synthese* 51(2): 141–167. https://doi.org/10.1007/bf00413825

Rouse, J., 1987. *Knowledge and Power: Toward a Political Philosophy of Science*. Ithaca: Cornell University Press.

Stepin, V., 2005. *Theoretical Knowledge*. Springer.

Vihalemm, R., 1981. Ühe teaduse kujunemislugu. Tallinn: Valgus.

Vihalemm, R., 1993. Teadusfilosoofia ilma filosoofiata. *Akadeemia* 9: 1800–1817.

Vihalemm, R., 1999. Can chemistry be handled as its own type of science? *Ars mutandi: Issues in Philosophy and History of Chemistry,* Leipzig: Leipziger Universitätsverlag, 83–88.

Vihalemm, R., 2001. Chemistry as an interesting subject for the philosophy of science. Estonian Studies in the History and Philosophy of Science. R. Vihalemm (Ed.). *Boston Studies in the Philosophy of Science*. Vol. 219: 185–200. Dordrecht: Kluwer. https://doi.org/10.1007/978-94-010-0672-9_14

Vihalemm, R., 2003a. Are laws of nature and scientific theories peculiar in chemistry? Scrutinizing Mendeleev's discovery. *Foundations of Chemistry* 5(1): 7–22.

Vihalemm, R., 2003b. Is chemistry a physical science, a physics-like science or its own type of science? Volume of Abstracts. 12th International Congress of Logic, Methodology and Philosophy of Science, Oviedo: Universidad de Oviedo, 348–349.

Vihalemm, R., 2004. The problem of the unity of science and chemistry, In Chemistry in the Philosophical Melting Pot, D. Sobczynska, P. Zeidler, & E. Zielonacka-Lis (Ed.), 39–58. Frankfurt-am-Main: Peter Lang Verlag.

Vihalemm, R., 2005. Chemistry and a theoretical model of science: On the occasion of a recent debate with the Christies, *Foundations of Chemistry* 7(2): 171–182. https://doi.org/10.1007/s10698-005-0959-y

Vihalemm, R., 2007a. Philosophy of chemistry and the image of science*, Foundations of Science* 12(3): 223–234.

Vihalemm, R., 2007b. A. Whitehead's metaphysical ontology and I. Prigogine's scientific ontology: from a point of view of a theoretical conception of science, *Problemos* 71: 78–90.

Vihalemm, R., 2011a. The autonomy of chemistry: Old and new problems, *Foundations of Chemistry* 13(2), 97–107.

Vihalemm, R., 2011b. Towards a practical realist philosophy of science, *Baltic Journal of European Studies* 1(1): 46–60.

Vihalemm, R., 2012. Practical realism: Against standard scientific realism and antirealism, *Studia Philosophica Estonica* 5(2), 7–22. https://doi.org/10.12697/spe.2012.5.2.02

Vihalemm, R., 2013. What is a scientific concept? Some considerations concerning chemistry in practical realist philosophy of science, in: The Philosophy of Chemistry: Practices, Methodologies and Concepts, J.-P. Llored (Ed.): 364–384). Cambridge: Cambridge Scholars Publishing.

Vihalemm, R., 2015. Philosophy of Chemistry against Standard Scientific Realism and Anti-Realism. *Philosophia Scientiae* 19 (1): 99–113. https://doi.org/10.4000/philosophiascientiae.1055

Vihalemm, R., 2016. Science, φ-science, and the dual character of chemistry. In E. Scerri & G. Fisher (Eds.), *Essays in the philosophy of chemistry*: 352–380. Oxford: Oxford University Press.

Vihalemm, R., 2019. A Story of a Science: On the Evolution of Chemistry, *Acta Baltica Historiae et Philosophiae Scientiarum* 7 (2): 8–179. https://doi.org/10.11590/abhps.2019.2.01