

Philosophy of Chemistry

by Eric Scerri

When I push my hand down onto my desk it does not generally pass through the wooden surface. Why not? From the perspective of physics perhaps it ought to, since we are told that the atoms that make up all materials consist mostly of empty space. Here is a similar question that is put in a more sophisticated fashion. In modern physics any body is described as a superposition of many wavefunctions, all of which stretch out to infinity in principle. How is it then that the person I am talking to across my desk appears to be located in one particular place?

The general answer to both such questions is that although the physics of microscopic objects essentially governs all of matter, one must also appeal to the laws of chemistry, material science, biology, and other sciences. Chemistry for example, may be essentially governed by the laws of quantum mechanics,

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but in order to study the nature and transformation of matter at the appropriate chemical level, one needs to appeal to laws of science other than just quantum mechanics. This realization that chemistry is

not fully "reduced" to quantum mechanics has been one of the main motivations for the recent resurgence in the philosophy of chemistry.

Before the turn of the 20th century chemistry was at the heart of philosophical issues in science. For example, it was almost exclusively chemists who conducted the atomic debates that followed the influential work of John Dalton. While some of them regarded atoms as entities that actually existed, others thought about them as mere convenient fictions. But following the discovery of radioactivity and the birth of quantum theory, the atom was snatched away from the chemist and the philosophical focus switched to physics, which had by this time also experienced the Einsteinian revolution in the study of space and time. Chemists began to be seen as people doing applied physics. As Dirac famously claimed, all of chemistry had been reduced to physics and all that remained was to clear up the details.

Of course, the field of computational quantum chemistry, which Dirac and other pioneers of quantum mechanics inadvertently started, has been increasingly fruitful in modern chemistry. But this activity has certainly not replaced the kind of chemistry in which most practitioners are engaged. Indeed, chemists far outnumber scientists in all other fields of science. According to some indicators, such as the numbers of articles published per year, chemistry may even outnumber all the other fields of science put together. If there is any sense in which chemistry can be said to have been reduced then it can equally be said to be in a high state of "oxidation" regarding current academic and industrial productivity.

Starting in the early 1990s a group of philosophers and chemists with philosophical leanings began publishing articles aimed at exploring the question of the alleged reduction of chemistry. Soon thereafter the International Society for the Philosophy of Chemistry was created. Its official journal, *Foundations of Chemistry*, has begun its fifth year of publication. Another international journal, called *Hyle*, also devoted to the field, had been launched earlier on the Internet but is now also available in paper form.

There has been a good deal of interest from the chemical education community, not surprisingly since educators regularly face philosophical choices as to how to best present the contents of chemistry courses and what kind of emphasis should be pursued. Returning to an earlier issue, there has been an ongoing debate about just how much quantum mechanics should be deployed in the teaching of general chemistry. Detailed studies on such questions are beginning to emerge from work in philosophy of chemistry and are being seriously considered by educators.

But philosophers of chemistry are also concerned with many other issues beyond the role of quantum mechanics. Philosophers of science have realized for some time that there has been too much focus on purely theoretical and logical aspects of science. There has been a gradual turn towards the study of scientific models and approximations as well as the nature of semi-empirical methods and instrumental techniques. In all these areas chemistry has begun to provide a rich selection of new case studies, especially given the less deductive nature of chemical theories as compared with those of physics.

The recent influx of philosophy into chemistry also



promises to clarify another important issue in chemical education. In recent years many science educators, and especially many chemical educators, have begun to support an approach referred to as constructivism. These authors correctly point out that students come to chemistry classes from a wide variety of backgrounds and with many preconceptions. They claim that it is a mistake to ignore the fact that students have constructed their view of scientific facts such as the nature of acids and bases to take just one example.

But in their eagerness to embrace this admittedly more enlightened educational approach, some of these chemical educators have unwittingly aligned themselves with constructivist claims about the manner in which mature scientific knowledge is arrived at by mature scientists. The claim of constructivists is that scientific knowledge is somehow socially constructed rather than being discovered. The dominant school of chemical education may therefore be on the wrong side of the recent and notorious Science Wars debate. Some chemical educators have even fallen prey to the related post-modern position of relativism without realizing that this is both self-defeating and essentially anti-scientific in spirit. If, as relativism maintains, all paths of knowledge are equally valid then why should anyone even want to support relativism itself in favor of any other philosophical approach?

Fortunately, articles emerging from the philosophy of chemistry have now begun to challenge the confusion that exists among some chemical educators. The ensuing debates might serve to distinguish between educational constructivism, which may be valid, from constructivism about scientific knowledge itself, which very few scientists are willing to concede to but which many chemical educators seem to draw inspiration from.

Then there are ethical questions that inevitably surround chemical synthesis and the chemical industry in general. As we all know chemistry receives more than its share of the blame for the environmental ills of today. One positive response from the chemical community has been the growth of the Green Chemistry initiative that aims to find environmentally friendly

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ways of producing industrial chemicals. The approach is essentially a philosophical one. The relationship between ethics and chemistry is being increasingly examined by some philosophers of chemistry.

The study of visualization and representation is another philosophical issue that has come increasingly to the fore with the development of chemistry and the parallel growth of computa-

tional power. Chemists are rather unique in frequently needing to visualize structures and entities that they also know not to exist according to the dictates of physics. Atomic and molecular orbitals are a good case in point. They are used as mathematical tools in quantum chemistry at all levels. Their use has been undeniably productive—as in the case of the Woodward-Hoffman rules in organic chemistry. And yet, from the perspective of quantum physics, any orbital is just a mathematical fiction devoid of any real existence just like the square root of the number minus one in mathematics.

But sometimes the zeal with which chemists like to embrace models and visualizations goes a little too far. Such was the case about three years ago when many scientific magazines reported the claim that textbook orbitals had been literally observed for the first time. These excesses were quickly corrected in the literature but the only people who took the trouble to do so were among the more reflective chemists and philosophers of chemistry.

There is another reason why philosophy of chemistry has been such a recent newcomer alongside the more established study of philosophical aspects of modern physics and biology. The reason is partly historical and partly due to the kind of systems one is dealing with in each of the three sciences. Of course, philosophers of science have tradi-



Source: Tim Lenoir, Stanford University

Feature

tionally concentrated on physics since it is the most fundamental science.

But fundamental does not necessarily mean more important. This is clearly seen if one thinks of biology. To living beings such as us there is an immediate sense in which biology is more relevant and more important than abstract theoretical physics. In the 1950s and '60s philosophers of science realized that they had concentrated too much on physics and that the general principles they had arrived at regarding the nature of science just did not apply to vastly different biological systems. They then quickly set about developing the philosophy of biology while completely leap-frogging over the complex and central science of chemistry. This response may seem to have been shortsighted in hindsight, but it is also perfectly understandable. Biology is very different in scale and nature from microphysics and the study of space and time. Chemistry on the other hand shares

many aspects with physics and biology and so philosophers persuaded themselves that a special study of how chemistry is different was not warranted.

Perhaps the time has now come for such a fine-grained approach to philosophy of science that seeks to distinguish between physics and chemistry, while at the same time respecting all its similarities. Likewise, philosophers of chemistry have begun to examine the interface between chemistry and biology. Given the richness and complexity of chemistry, which serves to link physics and biology, it is to be expected that the philosophical study of chemistry will eventually pay large dividends to our understand-

ing of science as a whole. Seen in this way, the delayed emergence of philosophy of chemistry is no longer mysterious but may be a direct outcome of its frequently noted central position among the natural sciences.

The rising interest in the field was quite evident at the sixth meeting of the International Society for the Philosophy of Chemistry that took place at Georgetown University in Washington, D.C., in August 2002. An audience of about 70 was able to choose

between papers given in three parallel sessions over the course of three days. Speakers included Kovacs (University of Kentucky), Vemulapalli (University of Arizona), Earley (Georgetown), Scerri (UCLA), Harré (Oxford), van Brakel (Leuven), Needham (Stockholm), Ramsey (Smith College), and Schummer (Karlsruhe), as well as chemical educators and historians interested in fundamental aspects of chemistry.

Finally, I would just like to mention that several excellent books have appeared on the subject of philosophy of chemistry. It has become clear that from being ignored in the past, this field is now the fastest growing sub-discipline within the philosophy of science. 🧠

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www.chem.ucla.edu/dept/Faculty/scerri
www.georgetown.edu/faculty/earleyj/ISPC.html

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