Book Review

Alan Rocke: *Image and Reality: Kekulé, Kopp, and the Scientific Imagination*, Chicago: University of Chicago Press, 2010, xxvi + 375 pp. [ISBN: 9780226723327]

by Stephen J. Weininger

Alan Rocke is one of our most accomplished and acute authorities on 19th-century chemistry, especially the rise of organic chemistry and its greatest conceptual achievement, the structural theory. His publications have given us a wealth of detail and fine-textured examinations of this period while, at the same time, circling back to certain leitmotifs that transcend specific historical events.

Those leitmotifs emerged early in Rocke's oeuvre. The Preface to his first book, *Chemical Atomism in the Nineteenth Century* (Ohio State UP, 1984), drew attention to scientists' inferential techniques, especially *transdiction*, defined by Maurice Mandelbaum as "deducing properties of unobservable from observable entities" (p. xiii). Rocke commented, "One of the strongest forms of transdiction has been used for theories of matter […]. It was only in the nineteenth century that transdiction was widely and successfully applied to the microcosm, and in no field earlier or more dramatically than in chemistry" (p. xiv). These two themes – inferring true properties of unobservable entities from experimental data, and chemistry's leading role in that achievement – loom large in *Image and Reality*.

A major focus of this new work is on molecular representations, mental and physical. According to Rocke, these representations were the key to 19th-century chemists' successful unveiling of a major stratum of the microworld. Related claims have become increasingly prominent among a number of chemists, historians, and philosophers concerned with the development of modern chemistry. Rocke embraces and amplifies those claims while placing them in the wider context of scientific creativity.

The first chapter of *Image and Reality* lays out many of the dichotomies that dominated 19^{th}-century chemical theorizing – chemical vs. physical atomism; static vs. dynamic atoms and molecules; conventional vs. realist interpretations of chemical formulas. It also introduces the British chemists Thomas Graham and Alexander Williamson, noteworthy for their commit-

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ment to molecular realism and dynamism, and their propensity for visual thinking. Williamson also had a powerful influence on Kekulé who, not surprisingly, is the hub around which the narrative revolves. Chapters 2 and 3 are devoted almost exclusively to Kekulé, as are substantial parts of Chapters 4, 7, and 10. Rocke has been writing about Kekulé since his thesis work (published 1976), and the present book contains the fullest treatment of the man and his work since Richard Anschütz's 1929 two-volume biography. Readers will find very detailed and, in my opinion, evenhanded discussions of priority disputes involving Kekulé – over the structural theory with Butlerov and over the cyclic structure for benzene with Loschmidt (a quarrel generated by 20th-century commentators rather than the principals).

Of greater significance is Rocke's placement of Kekulé firmly in the 'realist-mechanist' camp with respect to molecular structure, despite what some have seen as Kekulé's waffling on the subject. Rocke offers a variety of defenses for Kekulé – his vulnerable position before he obtained a professorship; the widespread restraint of 19th-century chemists in making epistemological and ontological claims; and so on. To assess Rocke's judgments, one needs to look closely at Kekulé's beliefs with respect to specific entities. Thanks to Clausius's work on the kinetic theory, Kekulé was converted to *molecular* realism, declaring in 1858, "the chemical molecule is identical to the physical gas molecule" (p. 258). (The term "molecular realism" means both that molecules are real physical entities and that their properties are accessible by physical and chemical means.) His view on the relationship of chemical and physical *atoms* was quite different, however. In 1867 Kekulé wrote that he did not believe in ultimately indivisible particles of matter (physical atoms) but did believe in the existence of chemical atoms, "those particles of matter which undergo no further division in chemical metamorphoses" (p. 225). Kekulé's caution was shared by many, and for good reason. Contemporary theorizing by physicists about atoms, such as Thomsen's vortex model, offered little to chemists seeking to account for valence and specific affinities.

The most pressing epistemological issue addressed by Rocke concerned what could legitimately have been said about the arrangement of chemical atoms within molecules, *i.e.* the molecular structure. Kekulé and other leading chemists were using atomic valencies to propose structures that could be evaluated against the proliferating experimental data. In consequence, the 1850s and 1860s saw a growing consensus emerge that reliable constitutional formulas, specifying the connectivities among molecules' constituent atoms, were accessible via chemical means. Their iconography became standardized largely through the efforts of Crum Brown and Frankland; Kekulé's 'sausage' formulas were *sui generis* and used by few others. Nonetheless, all who used constitutional formulas, of whatever stripe, issued disclaimers to the effect that they were *not* intended to show the *actual* positions of the atoms in space.

However, the possibilities for 'misinterpreting' structural formulas multiplied when they were cast in physical form. Kekulé used wooden versions of his 'sausage' atoms to propose several benzene structures, some of them virtually uninterpretable without reference to his models. Although hewing to the two-dimensionality of their graphic counterparts, ball-and-stick models (Hofmann, 1865) initially encountered much opposition and were used only pedagogically. However, van 't Hoff's explication of optical and other types of isomerism based on his and Le Bel's tetrahedral carbon hypothesis (1874) helped elevate models to the status of research tools, *and* encouraged the conviction that spatially accurate molecular structures were within reach. (Curiously, Kekulé was a bit grudging about the recognition accorded van 't Hoff.) The models had taken on a multivalent life of their own.

Rocke is intent on showing that the achievements of Frankland, Kekulé, van 't Hoff and others unfolded in a professional milieu increasingly open to visual theorizing, *i.e.* to manipulating visual images in order to construct hypotheses capable of empirical testing. As further evidence, he guides us through Hermann Kopp's *Aus der Molecular-Welt* (1882), which describes a fanciful, anthropomorphic journey through the world of atoms, molecules, and solutions; significantly, it achieved both commercial success and scholarly approbation. In sum, Rocke has made a thoroughly researched, cogently argued case that, thanks to their adoption of visual thinking and intrepid modeling, 19th-century chemists were pioneers in exploring sub-visible reality. They did so, it should be noted, in a century that witnessed a complete revolution in our understanding of vision and a fascination with optical instruments and visual spectacles, one in which the boundary between the visible and the invisible became increasingly indistinct.

In his last chapter, 'The Scientific Image-ination', Rocke situates his investigation within the wider framework of scientific creativity, and links it to a growing body of literature that seeks to rebalance the historiography of science. Calls for greater attention to and appreciation of the indispensable role of the visual imagination in numerous branches of science have escalated in the last few decades. Chemistry has not always been given its due in this revaluation, so Rocke's comprehensive effort is both needed and timely.

Image and Reality will undoubtedly provoke questions and speculations in the minds of readers, as it did in mine. For example, I wondered if the developments that enabled chemists to become masters of and preoccupied with the molecule contributed to a division of labor in the physical sciences, whereby the investigation of the atom was abandoned to physicists. The surfaces of the atomic models in molecular structures – whether they were spheres, tetrahedra, or sausages – became boundaries beyond which chemists felt they need not venture. As van ‘t Hoff famously averred, “we can treat problems of affinity in an absolutely trustworthy way […] without admitting anything concerning the nature of affinity or of the matter wherein the affinity is supposed to reside”.

On a more contemporary level, one might consider the reception of chemical representations by the lay public. It is well known that chemical *nomenclature* often provokes strong negative reactions among that public, especially when encountered in the supermarket. These reactions are generally dismissed as ‘chemophobia’. Curiously, chemical *models* seem to be regarded much more benignly, since images of them float through American TV advertisements for energy and pharmaceutical companies. Do the aesthetic characteristics of molecular models play a role in this discrepancy? (If so, did they also play a role in the acceptance by chemists of molecular models?) It seems less plausible that lay people make a distinction between molecules and substances, but it is worth noting that they do differentiate between *chemicals* (to be avoided at all costs) and *chemistry* (absolutely essential to the success of films, plays, concerts, romantic relationships, *etc.*). Clearly, the public attitude toward chemistry, chemicals, and their representations is a far more complex phenomenon than the catchall term ‘chemophobia’ can encompass.

Image and Reality has relatively few errors and typos; I list here a few that could lead to confusion. The end groups in the glycerin structure on p. 59 should read C^2H^2; the second formula for lactic acid (p. 129) should read $CH_3(HO)CHCO_2H$; the structure on p. 192 represents a semi-constitutional, not an empirical formula. Potentially more serious are the three different names beneath the formula of salicylic acid on p. 190. The format implies that all refer to the *same* isomer, which is incorrect. The name ‘salicylic acid’ denotes the 1,2-(ortho)-isomer, as shown; the names ‘(hydr)oxybenzoic acid’ and ‘paraoxybenzoic acid’ refer to other isomers, presumably the 1,3-(meta)- and 1,4-(para)- ones. These are minor matters; more substantial are the absence of a Table of Illustrations and the insufficiently detailed Index. There are no independent index entries for major subjects such as chemical (and physical) atoms (and atomism), sausage formulas, glyptic formulas, and so on. This slows down the reader wishing to zero in on a particular topic.

Nothing in the previous paragraph seriously detracts from Rocke’s outstanding achievement in this publication. The range and scrupulousness of the research; the careful and nuanced construction of the arguments; the detailed exploration of numerous contexts: all these insure that readers will return to this book over and over, and will be freshly rewarded each time.

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