

COMMENTARY

Johannes Wislicenus, Atomism, and the Philosophy of Chemistry

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Johannes Wislicenus (1835–1902) is known as the chemist whose work on the structure of lactic acid inspired van't Hoff's theory of the asymmetric carbon atom, and who then sponsored the translation into German of van't Hoff's *La chimie dans l'espace* (1875). He was subsequently forced to suffer the scorn of Hermann Kolbe, who in his attack on stereochemistry declared Wislicenus to have left the arena of the exact sciences. Naturally, Wislicenus thought otherwise, but his side of the story, surprisingly, has never been told (1). As the earliest and strongest supporter of van't Hoff's theory of the tetrahedral carbon atom, Wislicenus clearly recognized the implications that the study of "chemistry in space" entailed for both chemical theory and practice, and he was willing to endure the criticisms brought about by his scientific commitments. The ability to study the arrangement of atoms in space, declared Wislicenus, was a definite sign of progress for the science of chemistry.

In 1888 Wislicenus published a clear and succinct defense of the then young science of stereochemistry, as a reply to a request from Wilhelm Lossen (1838–1906), professor of chemistry at the University of Königsberg (2). Despite its brevity, it reveals several aspects of Wislicenus' theoretical and methodological commitments, and therefore occupies a central position for understanding his science. I present here some introductory comments on the historical context of the paper, followed by a translation of the complete text.

Wislicenus had long been sympathetic to the idea that knowledge of spatial relationships of atoms was necessary for the success of chemical theory. He himself never found success, however, in producing a satisfactory way of investigating these relationships. During his

decade-long research on the constitution of the lactic acids, he struggled to interpret the differences he found (primarily the appearance of optical rotation) between the four known acids, and invented the term "geometrical isomerism" to indicate that these differences could be traced back to some sort of difference in the three-dimensional arrangements of the constituent atoms (3). He was unable to produce anything more concrete than this vague insight. It was not until the fall of 1875, when he became acquainted with van't Hoff's theory of the asymmetric carbon atom, that he realized what kind of three-dimensional arrangement would be useful for chemical theory.

In 1873, Wislicenus had reached a theoretical dead-end and had abandoned the further study of lactic acid, in part because of experimental difficulties in preparing pure samples of lactic acids. More importantly, however, another source of his frustration can be found in the traditional theoretical interpretation of the term "structure" that confined Wislicenus to a particular interpretation of chemical notation. According to its original meaning, as envisaged by August Kekulé and later clarified by Aleksandr Butlerov, a chemical structure represented the chemical arrangements of atoms in a molecule, and represented those atoms as "chemically" indivisible units, and not as discrete parts of matter in space (4). The phrase "chemical structure" therefore meant something unique—a picture or summary of the chemical behavior of a substance towards other substances; it did not mean a picture of the actual physical form of the molecule (what it "actually" would look like, if we could see it). Before he read *La chimie dans l'espace* in the fall of 1875, Wislicenus always regarded chemical structures according to this accepted interpretation.



Johannes Wislicenus (1835-1902)

The solution to Wislicenus' dilemma lay, of course, precisely in the theory of the tetrahedral carbon atom that van't Hoff laid out in his short book. The founders of stereochemical theory, van't Hoff and Le Bel, interpreted "structural formula" in a way different from its original meaning and assumed that atoms shown to be located near another atom in the molecule's chemical structure were also located near that atom in the molecule's physical form. The original aim of both theories was an explanation of optical activity, but the beauty of van't Hoff's thesis in particular lay in the recognition that all chemical drawings could contain more information than their original purpose had implied (5). According to van't Hoff, structures did not simply

represent the sequence of chemical connections in a molecule, i.e., which atom was connected with which, but could also imply the spatial relationships between them. These spatial relationships were obtained by the assumption of an equivalence, or at least a correspondence, between the chemical structure of a molecule and its physical form. One could obtain a model of the physical form of a molecule by assuming each carbon atom in its chemical structure to have the physical form of a tetrahedron.

Van't Hoff offered a method for modelling the physical form for all organic molecules, in the process proposing a means of representing the connections between carbon atoms. He modelled single, double, and triple bonds by joining, respectively, two corners, edges, or faces, as depicted in Fig. 1. The model in Fig. 1 was incapable of rotation about the line containing the carbon atoms, and thus predicted the existence of two different spatial isomers (i.e. *cis* and *trans* isomers) when

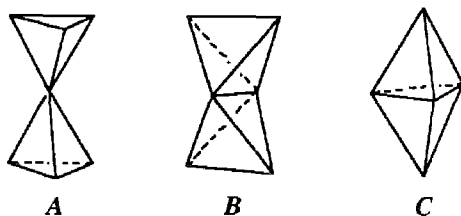
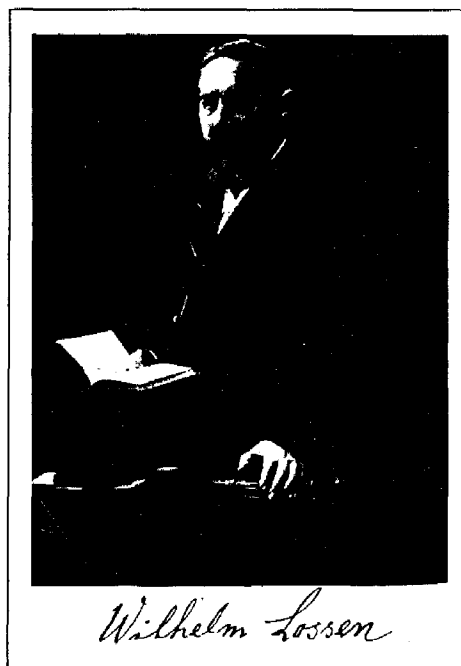


Figure 1 The van't Hoff-Wislicenus models for (A) single; (B) double; and (C) triple carbon-carbon bonds (after Wislicenus)

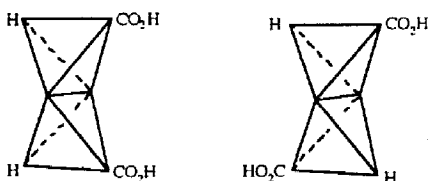


Figure 2 cis and trans isomers (after van't Hoff and Wislicenus)

each carbon atom contained two different radicals. This prediction accounted exactly for the existence of several known pairs of acids, such as maleic and fumaric acids (Fig. 2) that could not be differentiated theoretically by appealing to different chemical structures (that is, by connecting the atoms in a different way). Although van't Hoff's explanation of optical activity by means of the asymmetric carbon atom was generally adopted, this theory of geometrical isomerism in the unsaturated acids was ignored until 1885, when Wislicenus began his major work on the confirmation and expansion of van't Hoff's theory of unsaturation.

In the spring of 1887, Wislicenus published the results of these investigations in a major work entitled "On the Spatial Arrangement of Atoms in Organic Molecules and its Determination in Geometrically Isomeric Unsaturated Compounds" (6). Wislicenus adopted the models in Fig. 1 and provided a means of assigning *cis* and *trans* configurations (in Wislicenus' terms, "planesymmetric" and "axialsymmetric") to the unsaturated acids. In the 1877 edition of *Die Lagerung der Atome im Raume*, van't Hoff had already indicated a means of making such an assignment and had also given preliminary arguments for making such claims, but Wislicenus took these suggestions and elaborated upon them to reproduce a detailed version of van't Hoff's arguments, and applied the same reasoning to other pairs of acids. In the history of chemistry, Wislicenus' work occupies a unique position because of his explicit and comprehensive adoption of mechanical methods to solve chemical problems and its thoroughly mechanical attempt to explain chemical transformations. It is not necessary here to go into the intricacies of Wislicenus' mechanical arguments. They were complex and involved the consideration of intramolecular motions and chemical attractions, as well as the genetic chemical relationships of these acids to their derivatives.

Wilhelm Lossen responded to Wislicenus' paper in late December of 1887, directing his criticism to the van't Hoff theory and its assumptions about molecular

form in general, and not to Wislicenus' modifications (7). The argument was essentially a summary of his two earlier articles published in 1880 and 1881 on the nature of valence, which he defined simply as the number of atoms that were located in the "binding zone" of another atom (8). To Lossen, valence was a simple number indicated by the chemical structure and he made no commitment to a single valence number for any given atom (for example, carbon had a valence of either two, three or four). He found the concept of a multiple bond an absurd idea, since he interpreted this to mean that an atom could find itself in the "binding zone" of another atom twice; an atom was either there and bound or it was not. Presumptions of multiple bonds were an effort, in Lossen's view, to save the theory of constant valence, and rested furthermore on the assumption that atoms were divisible, since two different parts of an atom must attract two different corresponding parts on another atom. To be able to divide atoms in such a way, however, one must know what the atoms themselves were like, and at the current state of science, this was not accessible to observation.

Therefore, Lossen conceived of atoms as simple points, and gave the following simple analysis of the consequences of van't Hoff's theory. The theory of saturated compounds, that is, the model for optical activity and the model for single bonds, he found (9):

... compatible with the assumption that atoms are material points. The given figures become perhaps somewhat less clear, but not essentially changed, if all of the edgelines are removed. The endpoints of the remaining lines—dotted in the figures—then indicate the position of atoms in space, and their lines of bonding indicate the direction in which the force that unites the atoms with one another acts; this direction is exclusively dependent on the position of the atoms [Fig. 3].

He subjected van't Hoff's model for double bonds to the same analysis and found that it (10):

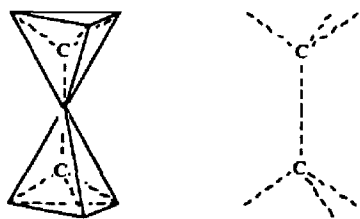


Figure 3 (after Lossen)

... can no longer be reconciled with the assumption that atoms are material points. It is not apparent therefore why in this case a rotation of the two triangles in opposite directions should not be possible [rotation about the C-C axis in Fig. 4]. Van't Hoff does not stop at [specifying] the position of atoms in space, but goes further, and also presents an arrangement of the affinity units in space, independent of the positions of the atoms ... In fact, the direction of lines CA and CB in Fig. 4 no longer indicates the position of atoms, since at A and B there are no atoms. In other words, in Fig 4 the affinity units possess an independent position in space.

The presumed restriction of rotation about the carbon-carbon bond, so crucial to van't Hoff's explanation of the isomerism between the unsaturated acids, was actually not possible if one followed Lossen in considering the position of point-mass atoms in space. Nor did the model for the double bond make physical sense to Lossen, since the lines of bonding did not lie along a straight line between the carbon atoms. The van't Hoff model had assumed that the atom had a shape and therefore had parts (11):

In my opinion [van't Hoff's] conception leads necessarily to the assumption that multivalent atoms cannot be considered as material points at all, that rather there are

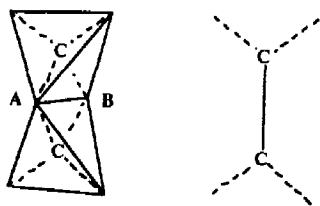


Figure 4 (after Lossen)

parts of them to distinguish, from which emanates their influence on other atoms.

Lossen then inquired how van't Hoff and Wislicenus could know anything of these parts.

It was unacceptable, according to Lossen, simply to speculate regarding the form of the carbon atom and its parts, and then construct the spatial properties of molecules. Although Lossen did not argue that the spatial distribution of atoms was unknowable, he did object to van't Hoff's claim to a knowledge of the spatial distribution of affinity units on the atom, that is, the shape of the atom itself. Lossen was quite specific about the sequence of events chemists should follow to gain knowledge of a molecule's spatial properties. One could only consider the position of atoms in space after the determination of the specific atomic form, and after the location of the seats of chemical affinity were located (12).

Lossen's critique was therefore methodological as well as theoretical. Van't Hoff and Wislicenus had addressed the problem exactly the other way around. They had first assumed an atomic form and a spatial distribution of affinities, bypassing completely even a preliminary definition of "affinity unit" (valence bond), and then constructed the form of molecules that led to certain observable predictions, namely the appearance of different configurational isomers. Lossen emphasized this "deficiency" in logic, and asked Wislicenus and van't Hoff to explain further what they actually meant in their models by affinity units.

This methodological criticism, that essentially advocated an inductivist over a hypothetico-deductive approach, provoked Wislicenus' response, which appeared in the *Berichte der deutschen chemischen Gesellschaft* in February of 1888. Wislicenus simultaneously defended the principles of stereochemistry against Lossen's theoretical argument, and the use of hypothesis in chemical theory against Lossen's methodological criticism. Wislicenus had remarkable linguistic skills, and in a forceful and articulate manner in a scant four pages of the *Berichte*, he made many interesting and insightful observations about the nature of chemical theory (13).

Two aspects of Wislicenus' scientific thought dominate this paper. First, and most obvious, is his explicit commitment to a physical atomism that would benefit chemical theory. Early in his career he followed the traditional interpretation of structural formulas, and separated the belief in indivisible physical atoms from his interpretation of chemical formulas. In his 1859 *Doktorarbeit* and *Habilitationsschrift*, "The Theory of

Mixed Types," he ascribed no physical reality to chemical formulas whatsoever, and considered them only as reaction formulas. Until his major 1887 work on stereochemistry, he made no public statements on the use of a physical atomism for chemical theory (14).

During his extended study of the lactic acids during the 1860s and 1870s, he attempted to reach definite conclusions about the physical arrangements of atoms to explain the differences between them, but it was not until the fall of 1875, when he became acquainted with van't Hoff's theory, that he saw a way that a physical atomism could be applied to chemical theory. By 1885 or 1886, when he began his study of the unsaturated acids, and probably much earlier, he had completely accepted van't Hoff's premise of the correspondence between the chemical structure and physical form of molecules. And in 1888 he felt confident enough to present publicly his conception of those physical atoms.

What then, did Wislicenus mean by atoms? His 1888 paper was the most explicit public statement of his beliefs—he said that the carbon atoms were tetrahedrally-shaped carriers of chemical energy. But this statement must be considered carefully. It is clear elsewhere in his response to Lossen that Wislicenus did not regard the *Berichte* as the place for such lofty speculations, and he made them only out of courtesy to Lossen; he did not regard this belief by any means as scientifically justified. At the most, it was perhaps a hunch or a feeling, based on his work so far. He was, on the other hand, absolutely committed to a broad conception of a tetrahedral carbon atom, since he was convinced that the experimental evidence confirmed this basic assumption. Presumably, he did not want to be "tied down" to a specific interpretation of the nature of the tetrahedron, i.e. the ultimate stuff that composed it, the actual cause of chemical affinity, or to the precise nature of the affinity unit, as Lossen had requested. These reservations no doubt also were related to his methodological commitments.

Perhaps the most interesting aspect of Wislicenus' atomism was his conviction that spatial arrangements of atoms were "accessible to experimental test," and that the proof of these configurations led precisely to a deeper understanding of atoms and furthermore, to a knowledge of subatomic structure. The "Uratoms," as components of the recognized elementary atoms, were the carriers of chemical affinity. This was the closest he ever came to defining an affinity unit, but he fell short of actually producing a concrete definition, and he remained content merely to make an analogy between the Uratoms and atoms of compound radicals at a higher

level. The idea that the known elements were possibly divisible was not a new or unique idea with Wislicenus, as he himself was quick to point out. It can be found in the speculations of Adolphe Wurtz, August Kekulé, and Crum Brown in the development of structure theory, and permeates much of chemical thought in the 19th century (15). Particularly innovative here, however, was Wislicenus' conviction of the relationship he offered between the confirmation of stereochemical theories and a knowledge of subatomic structure (16).

After 1888, Wislicenus was never again as explicit about the nature of these Uratoms. In a lecture given in 1892, in honor of the 25th anniversary of the Deutsche Chemische Gesellschaft and the observance of the death of A.W. Hofmann, and in 1893, in a tantalizing lecture given as the Rector of the University of Leipzig, "Chemistry and the Problem of Matter," he discussed similar ideas as in 1888, without going into as much detail about the actual nature of these Uratoms (17).

Wislicenus' response to Lossen also offers clues about his methodological and epistemological commitments. It is only through the manipulation of molecules, said Wislicenus, that chemists have gained knowledge about the nature of the constituent atoms, and the same process will elucidate the nature of the parts of those atoms. This, Wislicenus claimed, put him squarely in the middle of traditional research in organic chemistry. He considered research on geometrical isomerism to be a natural outgrowth of that empirical, inductive tradition.

Wislicenus declared at the same time, however, that the study of geometrical isomerism departed from this tradition, because it emphasized a deductive methodology. The theory of the tetrahedral carbon atom was not a cautious hypothesis, built from the slow accumulation of facts and observations. On the contrary, it was a set of bold assertions about the physical nature and actual appearance of carbon atoms and of organic molecules, and could not be confirmed by direct experience. It was precisely this speculative aspect of the theory that had provoked Lossen's criticism.

Speculation, Wislicenus admitted, was less certain than the cautious method of induction, but it nonetheless provided a quicker path to successful theories, provided such speculations could be supported by empirical investigation. They certainly may be wrong, but that should not prevent us from making them and testing them. Wislicenus made similar comments about the usefulness of hypotheses in a long letter to Hermann Kolbe defending van't Hoff's theory. Since new hypotheses generate new facts, even if these hypotheses be wrong, the facts they generate could be reinterpreted by later

generations of chemists to create a better theory. The future, and not the present, Wislicenus declared, was the best judge of scientific work (18).

Among organic chemists of his generation, he was perhaps the most explicit about the usefulness of hypotheses in chemistry. He advocated vigorously the advantages of hypotheses and the imagination not only in 1888 but also in his 1892 and 1893 lectures, and recognized in fact a methodological change from a predominantly inductive chemistry earlier in the century to a predominantly deductive chemistry that depended on the imagination. Like the incorporation of physical atomism into chemical theory, Wislicenus' scientific life was also coincident with a conversion of chemistry from an inductive, natural-history oriented science, to a theory-driven science that depended on the empirical confirmation of predictions (19).

With his commitment to a physical atomism and to a deductive chemistry, Wislicenus perceived clearly the existence of new trends in the theory and methodology of chemistry, and promoted these trends vigorously. He was prepared to endure the complaints and criticisms of Lossen and others who thought he took stereochemical principles too far, and who thought he had not remained tied to the facts. In part these criticisms were justified; he was almost too eager to see his principles work, and thought spatial properties would solve all difficult cases of isomerism. As Arthur Michael would show in the 1890s, some of Wislicenus' conclusions rested on empirically shaky ground (20). But Wislicenus' occasional overenthusiasm does not detract from his reasoned and articulate defense of stereochemistry. He clearly and gratefully acknowledged the debt he owed to past theoretical accomplishments in chemistry and to its inductive methodology, and indeed placed himself within these traditions, but would never agree with his opponents that chemists should be permanently fastened to them.

The following translation is an attempt, if it is possible, to be both literal and free, and I have also attempted to recreate Wislicenus' style as much as possible. Wislicenus held strong opinions, in religion and politics as well as chemistry, and was able to express them articulately and forcefully, both in print and in speech. It is, I believe, one of the factors that contributed to his influence in stereochemistry. Several German words that are difficult to translate have been included in the text, and all emphases are Wislicenus'. W. V. Farrar translated small portions of the text in 1968, and I have diverged considerably from his version. The most significant departure is explained in the notes.

ACKNOWLEDGMENTS

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REFERENCES AND NOTES

1. To date, the best and most sympathetic account of Wislicenus' life is by his assistant, colleague and friend at Leipzig, Ernst Beckmann, "Johannes Wislicenus," *Ber.*, 1904, 37, 4861-4946. I am currently evaluating Wislicenus' contribution to stereochemical theory.
2. J. Wislicenus, "Ueber die Lage der Atome im Raum. Antwort auf Lossen's Frage," *Ber.*, 1888, 21, 581-585.
3. N. Fisher, "Wislicenus and Lactic Acid: The Chemical Background to van't Hoff's Hypothesis," in O.B. Ramsey, ed., *Van't Hoff-Le Bel Centennial*, American Chemical Society, Washington, DC, 1974, pp. 33-54.
4. A. J. Roche, "Kekulé, Butlerov, and the Historiography of the Theory of Chemical Structure," *Brit. J. Hist. Sci.*, 1981, 14, 27-57, and *idem*, *Chemical Atomism in the Nineteenth Century: From Dalton to Cannizzaro*, Ohio State University Press, Columbus, 1984.
5. Le Bel made no such commitment, and considered each class of organic compounds separately. He agreed with van't Hoff only in his explanation of optical activity.
6. J. Wislicenus, "Ueber die räumliche Anordnung der Atome in organischen Molekülen und ihre Bestimmung in geometrisch-isomeren ungesättigten Verbindungen," *Abhandlungen der mathematisch-physischen Classe der königlichen sächsischen Gesellschaft der Wissenschaften*, 1887, 14, 1-77; the article was translated early in this century: "The Space Arrangement of the Atoms in Organic Molecules and the Resulting Geometrical Isomerism in Unsaturated Compounds," pp. 61-132, in G. M. Richardson, Ed., *The Foundations of Stereochemistry: Memoirs by van't Hoff, Le Bel and Wislicenus*, American Book, New York, 1901. I have retranslated the title.
7. W. Lossen, "Ueber die Lage der Atome im Raum," *Ber.*, 1887, 20, 3306-3310. Arthur Michael (1853-1942) began the other, ultimately more devastating criticism in 1888; see "Zur Kritik der Abhandlung von J. Wislicenus. 'Ueber die räumliche Anordnung der Atome in Molekülen,'" *J. Prak. Chem.* 1888, 36, 6-39.
8. W. Lossen, "Ueber die Vertheilung der Atome in der Molekel," *Ann.*, 1880, 204, 265-364 and "Ueber die

- sogenannte Verschiedenheit der Valenze eines mehrwertigen Atoms," *Ber.*, 1881, 14, 760-765.
9. "Die vorstehenden Ausführungen, deren Einzelheiten besonders in der ersten Auflage von van't Hoff's Broschüre entwickelt sind, sind vereinbar mit der Annahme, dass die Atome materielle Punkte seien. Die gegebenden Figuren werden vielleicht etwas weniger deutlich, der Sache nach aber nicht geändert, wenn man alle in denselben gezeichneten Kanten weglässt. Die Endpunkte der bleibenden (-in den Figuren punktiren-) Linien bezeichnen dann die Lage der Atome im Raum, die Verbindungslinien derselben die Richtung, in welcher die Kraft, welche die Atome mit einander vereinigt, wirkt; diese Richtung ist ausschliesslich abhängig von der Lage der Atome," Lossen, reference 7, p. 3307.
 10. "Diese letzere Auffassung lässt sich nicht mehr vereinigen mit der Annahme, dass die Atome materielle Punkte seien . . . Sodann ist nicht einzusehen, weshalb in diesem Fall eine Drehung der beiden Dreiecke im entgegengesetzte Sinn um die Linie CC nicht möglich sein soll . . . bleibt er [van't Hoff] nicht stehen bei der Lage der Atome im Raum, er geht darüber hinaus und stellt auch noch eine von der Lage der Atome unabhängige Lage der Affinitätseinheiten im Raum dar . . . In Fig. 4 dagegen ist die Richtung der Linien CA und CB nicht mehr gegeben durch die Lage der Atome, denn in A und B befinden sich keine Atome. Mit anderen Worten, in Fig. 4 besitzen die Affinitätseinheiten eine selbstständige Lage im Raum," *ibid.*, p. 3309.
 11. "Diese Auffassung führt nach meiner Meinung notwendig zu der Annahme, dass das mehrwertige Atom sich überhaupt nicht als materieller Punkt betrachten lässt, dass vielmehr Theile desselben zu unterscheiden sind, von welchen die Wirkung auf anderen Atome ausgeht," *ibid.*
 12. Lossen, reference 7, p. 3309.
 13. His linguistic abilities were apparently not limited to German. His English students also indicated an excellent proficiency with English, although he never published in it. This likely was primarily due to his three-year residence in America, although it seems likely he learned English in Germany before then.
 14. J. Wislicenus, "Theorie der Gemischten Typen," *Zeit. Gesamm. Naturwissen.*, 1859, 14, 96-175. According to Nicholas Fisher, Wislicenus was already thinking in three dimensions as early as 1863. At that time, however, Wislicenus did not have any concrete ideas about the nature of the physical form of molecules. This is supported by two observations. First, in 1863 Wislicenus continued to use the old type theory notation, which did not lend itself easily to three dimensional thought. Second, in 1863, when Wislicenus elaborated on the meaning behind chemical notation, he spoke primarily of different pictures of molecules with regard to their chemical behavior, and not to their physical form. See Fisher, reference 3, p. 43.
 15. See A. J. Roche, "Subatomic Speculations and the Origin of Structure Theory," *Ambix*, 1983, 30, 1-18, and W. V. Farrar, "Nineteenth Century Speculations on the Composition of the Elements," *Brit. J. Hist. Sci.*, 1965, 2, 297-323.
 16. Wislicenus' belief in simpler atoms was also noted by W. V. Farrar, "'Chemistry in Space' and the Complex Atom," *Brit. J. Hist. Sci.*, 1968, 4, 65-67.
 17. J. Wislicenus, "Die wichtigsten Errungenschaften der Chemie im letzten Vierteljahrhundert," *Ber.*, 1892, 25, 3398-3410 and *Die Chemie und das Problem von der Materie*, Edelman, Leipzig, 1893.
 18. Wislicenus to Hermann Kolbe, 24 November 1877. Standnummer 3550, Archives, Library of the Deutsches Museum, Munich.
 19. Alan J. Roche has pointed out this trend which occurred in the mid-19th century, and has assigned it as a possible cause for the pathological nature of Hermann Kolbe's attacks on structural chemistry as well as against Wislicenus and van't Hoff. See A. J. Roche, "Kolbe vs. the 'Transcendental Chemists': The Emergence of Classical Organic Chemistry," *Ambix*, 1987, 34, 156; for a more general exploration of this trend earlier in the century, see also A. J. Roche, "Methodology and Its Rhetoric in Nineteenth-Century Chemistry: Induction versus Hypothesis," in E. Garber, Ed., *Beyond History of Science: Essays in Honor of Robert E. Schafeldt*, Lehigh University Press, Bethlehem, 1990, pp. 137-155.
 20. Michael, reference 7, and "Untersuchungen über Alloisomerie. II." *J. Prakt. Chem* 1892, 46, 209-305; 381-427, "Untersuchungen über Alloisomerie. III." *J. Prakt. Chem* 1895, 52, 289-372.
 21. The figure of Wislicenus is taken from *Alma Julia. Illustrierte Chronik ihrer dritte. Seularfeier*, Thein, Wurzburg, 1882, p. 107.

ABOUT THE AUTHOR

Peter J. Ramberg was in residence at the Library of the Deutsches Museum in Munich in 1991-1992 as a Fulbright pre-doctoral fellow and completed his Ph.D. dissertation on the early history of stereochemistry at Indiana University the following year. He currently teaches general and organic chemistry in the Department of Chemistry, North Dakota State University, Fargo, ND 58105-5596.