BOOK REVIEWS

Methods and Styles in the Development of Chemistry. Joseph S. Fruton, American Philosophical Society, Philadelphia, PA, 2002; xviii + 332 pp, Cloth, ISBN 0-87169-245-7; $40.

Winner of the 1993 Dexter Award in the History of Chemistry, Dr. Fruton is best known for his work on the history of biochemistry and, more recently, for his essays and autobiography. This small, attractive volume represents his first venture into the general history of chemistry and is very much in the tradition of the well-known short histories of chemistry by Partington and Leicester, both of which are still available as quality Dover paperbacks. Like its predecessors, the book tends to emphasize the lives of famous chemists and, like them, its coverage of 20th-century developments after 1925 is minimal at best. However, Dr. Fruton has a lighter, more discursive writing style, which makes his book a much better read, and has availed himself of much of the recent secondary literature in the history of chemistry, as is apparent from the excellent notes appended to the end of the book.

The book is divided into ten chapters which are thematic in content but also roughly chronological in terms of when the topics in question became historically important. Protochemistry is covered in the first chapter under the title "The Greek Inheritance and Alchemy," followed by two chapters dealing with the 17th and 18th centuries ("Chemical Composition and Phlogiston" and "Antoine Lavoisier"), five dealing with 19th-century developments ("Atoms, Equivalents, and Elements;" "Radicals and Types;" "Valence and Molecular Structure;" "Stereochemistry and Organic Synthesis;" and "Forces, Equilibria, and Rates"), one dealing with the 20th century ("Electrons, Reaction Mechanisms, and Organic Synthesis"), and a final "Conclusion." I would strongly recommend this book as a possible text for a one-quarter or one-semester history of chemistry course directed at chemistry majors. That said, however, there are also some caveats to that recommendation, though I am loath to place the responsibility for these solely on Dr. Fruton and suspect that many of them are due to the publisher and editors since they apply equally well to much of the recent literature in the field.

The first deals with the book's title. There was a time when academic books had honest titles which succinctly summarized their contents and intended use, such as "A Short History of Chemistry", "An Introductory History of Chemistry", etc., but starting in the 1970s it became fashionable to base titles either on catchy "in the know" phrases (e.g., "Atoms and Powers") or grandiose higher historical or cultural themes (e.g., "Enlightenment Science in the Romantic Era") with only the subtitles following the colon giving any real concrete information about the book's actual contents. Though Dr. Fruton has been a keen critic of much of this historical silliness, as witnessed by his essays and the conclusion to the book under review, he nevertheless appears to have fallen into this trap himself. The title "Methods and Styles in the History of Chemistry" surely suggests a special emphasis on instrumental and procedural innovations (methods) and a detailed study of each scientist's published works in order to identify philosophical choices, favored approaches to problem solving, preferences for certain types of experimental or theoretical argument, etc. (style). But nothing of this sort is apparent in this book beyond a general discussion of this topic in the forward. As already pointed out, the special emphasis, if any, is biographical; and Fruton appears to use the term "style" in a highly idiosyncratic manner to denote what is, in reality, nothing more than a summary of a given chemist's research accomplishments.

A second criticism deals with the illustrations. In scientific writing illustrations are highly integrated with the text and serve to clarify difficult points. In contrast to histories of chemistry written by chemists, those written by historians are notable for their lack of illustrations. Though this has improved somewhat in recent years, one receives the impression that many of the illustrations used in their books have been added as a decorative afterthought; and the same appears to be the case with some of the illustrations in this book, few of which are discussed in any substantive manner within the body of the text or in the captions. Thus, though an entire chapter is devoted to chemical types, not a single type formula is illustrated, while an entire page is consumed in showing Faraday's apparatus for the measurement of electromagnetic rotation, a topic of little relevance to the history of chemistry.

A third criticism has to do with equations and formulas. According to historians, chemists who write about history of chemistry are usually guilty of two sins: whiggism and writing for other chemists. Though common sense would dictate that chemists are the most logical audience for books dealing with the history of chemistry, said historians have managed to delude themselves and their publishers into believing that there is a vast nonchemical audience for books of this type. Two unforeseen consequences of this delusion appear to be the assumptions that the use of chemical formulas and mathematical equations must be kept to an absolute minimum (and preferably banished to an appendix if possible) and that it is unnecessary to have a qualified chemist read the manuscript before publication. The result has been a proliferation of an embarrassing number of elementary chemical errors in recent history of chemistry publications. Examples include John Servos' definition of a reaction rate, in his otherwise excellent history of American physical chemistry community, as the change in concentration with respect to temperature (instead of time), and Elisabeth Crawford's painful page-long attempt, in her otherwise outstanding biography of Arrhenius, to verbally describe the factors involved in measuring the conductivity of an electrolyte solution, when reproduction of the appropriate equation would have made all instantaneously obvious.

The appearance of similar errors in Dr. Fruton's book is more puzzling since he is both an outstanding chemist and historian and, to judge from his acknowledgments, had various chemists review at least some portions of his manuscript. But they are there in abundance, especially in the chapter on "Forces, Equilibria and Rates," where the publisher has chosen to set the equations within the body of written text, rather than setting each on a separate line for proper emphasis, as is universally done in the technical and mathematical literature. Thus van't Hoff's isochore is incorrectly given (p. 176) as:

$$d\ln K/dT = \Delta\ln U/RT^2 \text{ instead of } d\ln K/dT = \Delta H/RT^2$$

The Arrhenius equation is incorrectly given (p. 176) as:

$$\ln k = Ae^{-E/RT} \text{ instead of } k = Ae^{-E/RT}$$

and the Nernst equation (written for some reason for a concentration cell rather than for a redox couple) is incorrectly given (p. 183) as

$$E = (RT/N)\mathcal{F}\ln(C_1/C_2) \text{ instead of } E = (RT/N\mathit{F})\ln(C_1/C_2)$$

Likewise on pages 173-174, Gibbs' equation from his 1873 memoir on graphical methods for the thermodynamics of fluids:

$$d\varepsilon = td\mu - pdv$$

is both incorrectly reproduced (Gibbs used η rather than μ for entropy) and incorrectly identified with his later free-energy equation:

$$\Delta G = \Delta H - T\Delta S$$

when in fact it is Gibbs' expansion of the equation for the first law of thermodynamics:

$$\Delta U = \Delta Q + \Delta W = T\Delta S - P\Delta V$$

and the free-energy equation does not appear until Gibbs' later memoir on the equilibrium of heterogeneous substances, where it is given in his notation as:

$$\zeta = \varepsilon - t\eta + pv$$

Finally, free-energy is represented as both ΔG and ΔF at various points in the chapter without explicit mention of the change in notation and E is used to symbolize both activation energy and electrochemical potential, also without comment.

A final criticism involves the coverage of 20th-century chemistry. As noted earlier, the short histories by Partington and Leicester have little to say about 20th-century events beyond the establishment of Bohr's model of the atom and early radiochemistry. Fruton does slightly better as he not only discusses these events, but also early electronic bonding models and the rise of physical organic chemistry to about 1966. However, nothing is said about colloid and surface chemistry, modern solid-state and inorganic chemistry, quantum statistical mechanics, or developments in the field of analytical chemistry.

Nevertheless, once these criticisms and limitations are apparent, it is easy enough for a teacher to provide the necessary corrections and supplements, and I stand by my earlier recommendation of this book. Indeed, I would rate it, along with Bill Brock's 1992 history, as one of the best short histories to appear in the last 40 years. *William B. Jensen, Department of Chemistry, University of Cincinnati, Cincinnati, OH 45221-0173.*

The German Chemical Industry in the Twentieth Century. John E. Lesch, Ed., Kluwer Academic Publishers, Dordrecht, Boston, London, 2000, viii + 449 pp. Hardcover. ISBN 0-7923-6487-2. Euro 163.50; $176.

This book, Volume 18 in the "Chemists and Chemistry" series from Kluwer, is a collection of 14 papers from a conference held at Berkeley, CA in March 1997. In the introduction by the editor, Department of History at Berkeley, the three themes of the volume are enumerated: research and development, impact abroad, and an account of the German chemical industry since 1945. Except for a short chapter on "I.G. Farben Revisited," the chapters are presented in Parts I-III according to the three themes. The first two papers in Part I—"Research and Technological Innovation"—by J. A. Johnson and D. Stoltzenberg (the recent Haber biographer) provide insightful descriptions of the effective research programs in the German chemical industry, with emphasis on the academic-industrial symbiosis in the period 1903-1939 and the particular roles played by Emil Fischer and Carl Duisberg. The impact of World War I is described here and also in the following paper by M. Szöllöse-Janze, "Losing the War but Gaining Ground: The German Chemical Industry during World War I." In the following chapter by P. Löhnert and M. Gill, the handling of Jewish scientists and those married to Jews at I.G. Farben's Agfa Filmfabrik Wolfen in the 1930s is documented. A. N. Stranges describes Germany's synthetic fuel industry, 1930-1945, in the last paper in Part I.

The four papers in Part II deal with the interaction of Germany chemical industry with Great Britain, Japan, and the United States. U. Marsch makes a case for the development of a strong British chemical industry, with the German's as model. This included formation of British Dyestuffs Ltd., founding of numerous research associations (modeled after the Kaiser-Wilhelm Institutes), and initiation of governmental financial support for industry. A. Kudo describes the opening in Japan of operations in dyestuffs, ammonia, and synthetic oil by I. G. Farben in the 1920s and 1930s. For this reviewer, one of the most revealing accounts is found in the paper by M. Wilkins, "German Chemical Firms in the United States from the late Nineteenth Century to the post-World Ware II Period." Here the reader can follow the fate of German firms established in the U.S. before World War I, their demise, and rejuvenation after 1945. The Bayer aspirin saga is an especially dramatic example. These international negotiations between the two world wars are further explored by K. Steen from the political point of view in the final paper in Part II.

Part III, "The Industry since 1945," is made up of four papers by social scientists. In the first, the legacy of anti-Semitism is treated by means of the Richard Willstätter controversy. The second covers the often short-sighted and selfish handling by the Soviets of chemical industry in East Germany after 1945. Next comes an overview of developments in chemical industry in the 1980s in the U.S., Japan, and Western Europe (not limited to Germany). The final chapter by R. Stokes provides an overview of the conference and poses the question as to what additional research remains for historians of the German chemical industry in the 20th century.

The authors have consistently substantiated their presentations with documentation in the form of lists and tables. While this strengthens the narrative, it makes for heavy reading. (This reviewer managed to get through the book over the period of a year.) Yet the volume is a valuable resource for anyone who seeks an overview of the evolution of the Germany chemical industry. Chemists will probably find less compelling those papers dealing with social, economic, and political impact. This reader was gratified by the straightforward account of Emil Fischer's suicide (p 87), so often overlooked or even denied. Inevitably one finds overlap and repetition of some aspects of the subject from chapter to chapter: background settings, the Jewish dilemma, impact of wars, the reaction to the economic depression, the Kaiser-Wilhelm Institutes (later Max-Planck Institutes). Although errata appear throughout the book, some of them can be attributed to oversights in translation ("trinitrotoluol," e.g.). *Paul R. Jones, University of Michigan*.

The Philosophy of Robert Boyle. Peter R. Anstey, Routledge, London, 2000. xv + 231 pp. $90.

The last fifteen years have seen a wave of new scholarship on Robert Boyle that has recast the old image of him as the "father" of modern chemistry, to a mechanical philosopher firmly embedded in the world and thought of seventeenth-century natural philosophy. We now know more, for example, about Boyle's development as a natural philosopher and theologian and his intense interest and participation in the alchemical tradition. Boyle has long been regarded as one of the founders of the mechanical philosophy in the seventeenth century, and historians have also recently articulated more precisely the specific influences on Boyle's corpuscularianism. Yet Boyle's style as a writer, and his known public disdain for proclaiming and creating explicit overarching "systems" of nature, have precluded an efficient systematic analysis of Boyle's mechanical philosophy. In *The Philosophy of Robert Boyle*, Anstey attempts to reconstruct the fundamental assumptions underlying Boyle's mechanical philosophy, including the primary qualities of matter, the nature of causation, natural law, motion and place, and the interaction of the corporeal realm of brute matter with the incorporeal realm of spirit and God.

The first part of the book treats Boyle's theory of the qualities. It is well known that Boyle considered size, shape, motion, and texture of atoms to be the primary qualities of bodies. Yet as Anstey points out, Boyle was not explicit as to why he chose these properties as primary and not others such as extension, indivisibility, or impenetrability. From a close reading of Boyle's *On the Origin of Forms and Qualities*, Anstey offers a classification of qualities according to Boyle and suggests two reasons for Boyle's choice of primary qualities. The first involved reasoning from the corpuscles themselves towards the sensible qualities, termed by Anstey the "bottom-up approach." The second mode of reasoning moved in the opposite direction, from Boyle's general reductive principles (termed the "top-down approach" by Anstey), by which all sensible qualities are reduced to increasingly smaller concretions of corpuscles until reaching the individual atoms. Anstey concludes that Boyle ultimately remained agnostic about the primacy of properties such as infinite indivisibility and impenetrability of matter, but matter without the properties of size, shape, and texture was inconceivable to him. Having discussed the nature of Boyle's primary qualities, Anstey then moves on to unravel Boyle's complex ontology of the sensible (nonmechanical) qualities and their relation to the mechanical qualities. Such an understanding is important for uncovering Boyle's stance on the sensible qualities, a central issue in the mechanical philosophy, and more precisely, his influence on Isaac Newton's form of corpuscularianism and John Locke's well known differentiation of the primary and secondary qualities.

In the second half of the book Anstey turns to Boyle's concept of motion and the nature of Boyle's "mechanism" in the mechanical philosophy. Boyle did not offer a comprehensive mathematical theory of motion that departed from or elaborated on Descartes' or Galileo's detailed treatment of motion; but it does seem clear that Boyle thought a great deal about motion and its importance in understanding the nature of causation and natural law in the mechanical philosophy. For example, like many of his contemporaries, Boyle clearly rejected the scholastic distinction between "natural" and "violent" motions. Because he was primarily concerned with explicating the qualities of bodies and not their motion or place, Boyle usually discussed the concept of "place" as in his theological and epistemological works, and not in his discussions of the mechanical philosophy proper. An understanding of motion was also central to Boyle's concept of natural law, God's relationship to his creation, and the interaction of mind and body. After extensively examining each of these issues in Boyle's works, Anstey suggests that Boyle was a "nomic occasionalist," meaning that the causal interaction of bodies required that God intervene in a law-like way. Boyle's recourse to this nomic occasionalism allowed him to avoid the deistic implications of the mechanical philosophy, while recognizing that nature itself could have a hand in causing phenomena.

Anstey is well versed in the Boyle corpus, relying on well known works such as *A Free Inquiry into the Vulgarly Received Notion of Nature*, *The Origin of Forms and Qualities*, and *The Christian Virtuoso* as well as lesser known works. His analysis also relies on a good knowledge of the current historiography on Boyle; with some exceptions he fits his own conclusions within that framework rather than offering an entirely new picture of Boyle. For example, Anstey notes that Boyle's alchemy fits well with his nomic occasionalism, as his attempt to locate the philosopher's stone was also a search for a tangible link between the material and spiritual realms. *The Philosophy of Robert Boyle* can be heavy reading at times for the author assumes a basic knowledge of seventeenth-century philosophical categories such as voluntarism, occasionalism, and concurrence; but it is worth a close examination for understanding the nature of Boyle's natural philosophy. *Peter J. Ramberg, Division of Science, Truman State University, Kirksville, MO 63501.*

Mendeleyev's Dream: The Quest for the Elements. P. Strathern, Berkley Books, New York, NY, 2000, 309 pp., ISBN 0-425-18467-6. $14.

Paul Strathern has written a very readable, brief popular history of the foundations of the chemical sciences. To those casual readers who want to understand the development of the chemical sciences Strathern has performed a marvelous service. A brief description of how Mendeleyev produced his periodic law in 1869 including the dream scenario ala Kekulé forms the prologue and setting for the rest of the book. Combining a background in chemistry, physics, mathematics and philosophy, this prolific author has produced a book that is both enjoyable to read and also provides delightful anecdotes in each chapter that teachers at all levels will find particularly useful.

The text is divided into 14 chapters arranged in chronological format. The first chapter deals with aspects of Greek natural philosophy concerning the structure of matter. In a concise manner the major ideas concerning the elements of Empedocles, Aristotle, and Plato are discussed. The second chapter deals with the foundations of alchemy in Alexandria, where the Greek philosophical tradition was blended with Egyptian technology to produce alchemy. Following the decline of Alexandria, alchemy had a rebirth in the new Arab civilization, which spread across the Middle East, North Africa, and parts of Europe. The contributions of the Arab alchemists Jabir, Al-Razzi, and Avicenna are discussed in detail.

The third chapter deals with Europe in the Middle Ages and the emergence of scientific thought and the conflict with the Roman church. The ideas of Roger Bacon are discussed to illustrate this point. The works of the Arab alchemists, having now been translated, were disseminated in Europe; and new discoveries of a practical nature were being made in the context of the age old attempt to find the mythical philosopher's stone. New laboratory techniques were invented and old ones improved upon by the European alchemists. The discovery of new substances is also found in this chapter.

A whole chapter is devoted to Paracelsus, whose life, accomplishments, and influence are reviewed in great detail. Many anecdotes about this remarkable person are given and to this reviewer this was one of the better chapters in the book. Paracelsus died two years prior to the publication of Copernicus's *Revolutions of the Heavenly Spheres* and the next two chapters are devoted to a brief but very readable analysis of the scientific revolution. Particularly interesting are the discussions of Nicolas of Cusa (1401-1464), who anticipated in many ways Copernicus and Giordano Bruno, whose radical ideas included the revival of the atomism of Lucretius. Galileo, Descartes, Gilbert, and Francis Bacon receive ample attention for their philosophical perspectives on the methodology of science.

In the next chapter, "A Born-Again Science," the important discoveries of van Helmont concerning the gaseous state and the use of quantitative methods are stressed. Strathern credits van Helmont as the founder of biochemistry and discusses the experiments that he performed that led to this appellation. Franciscus Sylvius , a pupil of van Helmont, continued his work and saw digestion as a chemical process involving acids and bases. He was able to extend these ideas to a description of the process of neutralization and the origin of salts. Through his experiments Sylvius was leading the way to the distinction between elements and compounds. An interesting anecdote in this chapter, typical of many found in the text, is the origin of the name for the drink gin. As Strathern relates, Sylvius developed a cure for kidney ailments by mixing distilled grain spirit flavored with juniper berries, called in Dutch *genever*. Although it failed as a cure-all, it became a popular drink and in English was abbreviated to gin.

The ideas of Robert Boyle on the composition of matter are also treated in this chapter. Boyle is shown to be typical of many of the scientific elite of his time in terms of their interest in theological matters and their self-deprecation of their scientific contributions. Boyle, fascinated by the work of Otto von Guericke, had Robert Hooke build an effective laboratory vacuum pump. This led to his law and the demystification of air as an element. Boyle's most significant practical chemical contribution was the development of an indicator for acids and bases prepared from an extract of the violet plant.

In Chapter 8 the discovery of several new elements, phosphorus by Brand in 1669, chlorine by Scheele in 1770, nickel by Cronstedt (1751), and platinum accidentally in 1735, make for fascinating reading. The material on Scheele was particularly enlightening given the short shrift he is accorded in most texts. "The Great Phlogiston Mystery" is discussed in the next chapter. The development of this theory of chemical transformations as developed first by Becher and extended by Stahl is given in detail. In the context of the phlogiston theory the work of the great English eccentric Henry Cavendish and the Unitarian minister-turned-chemist Joseph Priestley are found in this chapter. The discussion of their lives as presented will be useful as background for any general discussion of this period in the history of chemistry.

The last four chapters are the most disappointing. In a scant 70 pages the author takes up the Chemical Revolution, Dalton and the atomic theory, the work of Berzelius and Davy, as well the early attempts at the periodic classification of the elements. In the last chapter he returns to Mendeleyev in more detail. For the casual reader there is sufficient material to give a flavor of this crucial era in these four chapters.

This being a popular history, there are no footnotes in the text, although there are suggested further readings for each of the chapters at the end of the text. These include reference works, monographs, and journal articles. There is a seven-page index that will be helpful for finding specific points.

This reasonably priced book is not in the same category as Ihde's *The Development of Modern Chemistry* or Brock's *Norton History of Chemistry* but is aimed at a general audience. For practicing chemists and students of the discipline with little knowledge of the development of their field of study this book is an ideal first step. Along with the more scholarly recently published work of Trevor Levere *Transforming Matter* these make a good pair. *Martin D. Saltzman, Providence College, Providence, RI, 02918.*

Heinrich Caro and the Creation of Modern Chemical Industry. C. Reinhardt and A. S. Travis, Kluwer Academic Publishers, Dordrecht, Boston, London, 2000, *xxii* + 453 pp. ISBN 0-7923-6602-6. $189.

If William Henry Perkin (1838-1907) was responsible for the beginnings of the synthetic organic chemical industry, then, as this book makes clear, it was Heinrich Caro who made it possible for the industry to reach its full potential in the nineteenth century. Carsten Reinhardt and Anthony Travis have not only produced the first complete biography of Caro, but have also addressed questions as to what factors enabled the organic chemical industry to grow and prosper in Germany during Caro's lifetime. By following the growth of Caro's employer BASF, they have also given us an insight into what led Germany to become the preeminent chemical manufacturing power in the world.

This is a masterfully researched work, based upon a wealth of material deposited at the Deutsches Museum in Munich by Caro's daughter Amalie, as well as upon other primary and secondary sources. The authors' presentation is written on two levels, so that those without any knowledge of organic chemistry can follow the narrative with little difficulty, while those familiar with elementary organic chemistry will be better able to appreciate the key developments in the chemistry of synthetic dyes.

The text is divided into twelve chapters; the first two deal with Caro from his birth in 1834 until 1859 when he finished his apprenticeship as a calico printer. The next three chapters cover the years 1859-1866 which he spent in England, where he took part in the synthetic dye revolution. Chapters 6-9 are devoted to Caro's career at BASF, which lasted from 1868-1890. Chapters 10 and 11 summarize his life in terms of his accomplishments and failings, as well as the years from 1890 until his death in 1910, during which time he remained a member of the supervisory board of BASF and an observer of the dye industry. Finally in the last chapter the authors discuss the myth and history associated with Caro. The text includes 64 pages of notes, a twelve-page bibliography, and indexes according to dye type, name, and companies. There are numerous photographs and other illustrations.

Heinrich Caro was born in the town of Posen, East Prussia (Poznan, Poland), the son of Simon and Amalie Caro. His Jewish ancestry would play an important role in the shaping of his future career. In 1842 Caro's father decided to move to Berlin, where he felt the business opportunities and educational environment would be better for his sons. Caro's parents are best described as secular, but still rooted in Jewish tradition.

In Berlin, Caro attended the Kölnische Realgymnasium where he proved to be an indifferent student at first. He was very taken with literature and music and wrote rather bad poetry, we are told. Caro became interested in liberal politics and was an observer of the failed Revolution of March, 1848 in Berlin. Caro's opportunity to work in the chemical laboratory of the Realgymnasium in 1850 changed his life. He now became totally fascinated with chemistry. Despite some misgivings on the part of his father, but with the encouragement of his mother, Caro decided that chemistry would be his field of study.

In 1852 Caro completed his secondary school education and sought admission to Berlin's Königliches Gewerbeinstitut, the leading technical college in Prussia. Caro was very aware that even a secular Jew had very limited opportunities in the Prussian academic world. Therefore he did not seek a university degree but opted for the practical training of the trade school. Caro, "[d]riven by a combination of natural ability and the sure knowledge that in the future he would have to support himself, … spared no efforts with his studies." (p. 25). Caro's teachers were Karl Friedrich Rammelsberg and Gustav Magnus, also of Jewish descent. As pointed out by the authors, it was this lack of entry into the academic world which led men such as Caro—and other future graduates of the Gewerbeinstitut (from 1866 known as Gewerbeacademie) in the 1850s and 1860s, such as August Leonhardt, Ivan Levenstein, and Carl Liebermann—into the world of practical chemistry. This in turn would set the agenda for much academic research in the nineteenth century.

His teachers suggested that Caro consider a career in calico (cotton) printing as a textile colorist. Well paid employees, colorists were responsible for preparing and fixing dyes as well as creating designs. This required an apprenticeship, the posts for which were difficult to obtain. Caro was able to secure one at the C. & F. Troost printing factory in Mülheim in May, 1855. Only natural or semi-synthetic dyes were used. The authors present concise descriptions of the most important dyes of the time, particularly madder (the basis of Turkey Red) and its refined form known as garancine, as well as the role chemists played in their preparation and application.

Caro's apprenticeship was to last for three years; most of his salary going to pay for the instructions from the resident colorist at Troost, Achille Steinbach. Caro was willing to put up with long hours and miserable living conditions since he knew that, when his apprenticeship was completed, he would be qualified to teach the trade himself or obtain lucrative employment in the German textile industry. "Calico printing consumed his entire being. His perseverance and rapid progress, drawing on his chemical education and a philosophy of self-help, were to become the hallmarks of a man who would change the course of the history of dye technology." (p. 38). The authors provide an excellent description of the problems of using madder colors and include pictures and drawings of equipment used in the calico printing industry. In 1857, Caro's employer sent him to Manchester, England, where he was able to see for the first time the large-scale application of organic chemistry in the textile industry. Contacts were made with manufacturers and colorists that would lead, in the autumn of 1859, to his return to Manchester after completing his apprenticeship.

The authors devote three chapters to the Manchester years, 1859-1866, which were critical for Caro's later major contributions to the dye industry. In the autumn of 1859, armed with letters of introduction, Caro came to Manchester, which with Huddersfield, were the dye manufacturing centers in Great Britain. The industry was undergoing a major change from natural and semisynthetic dyes to the new synthetic aniline dyes discovered in 1856 by William Henry Perkin. Caro was hired by the firm of Roberts, Dale & Co., a leading Manchester manufacturer of textile chemicals.

During this period, Caro, as well as many other German trained chemists, worked for British dye manufacturers. The knowledge they obtained of experimental techniques and the manufacturing processes would be crucial to the future rise of the German chemical industry. The need for efficient marketing as well as a system of customer service was also an outgrowth of the experiences of these German visitors. The authors explain in great detail the invention of the whole range of aniline dyes during the 1860s.

Caro invented a new process for mauve and discovered an aniline black dye in 1862. This aniline black was superior to the natural black dyes derived from logwood and madder in calico printing. By 1864 dyers had a range of aniline dyes consisting of purple, red, blue, black, green, and violet. Other coal-tar dyes provided brown and yellow colorants.

Caro began to appreciate the value of the connection between the academic research laboratory and the synthetic dye industry. Key examples were the contract work performed by the German chemists Carl Schorlemmer (Owens College, Manchester) for Roberts, Dale & Co. and A. W. Hofmann (Royal College Chemistry, London) for firms in London. Carl Martius, an assistant to Hofmann in London, was induced by Caro to join Roberts, Dale & Co. in August, 1863. Martius would be instrumental in developing the first azo dyes. Shortly after his return to Germany in 1867 he and Paul Mendelssohn-Bartholdy co-founded a predecessor of AGFA.

As the authors make clear: "Liberality, tolerance, diversity, and mechanized textile production in Manchester wove together science and technology in ways that were not possible elsewhere in Europe." (p. 88). The seven years that Caro spent in Manchester were the most critical in his life, as he was to wed his training in the art of calico printing with the newly emerging synthetic dye industry.

The synthetic dye industry in the 1860s was a cutthroat business with scheming, double-dealing, and industrial espionage the norms. Alliances were formed and broken all in the name of improving profits and status of individual chemists and their employers. Caro seemed to have been able to acquit himself well in this environment and became one of the most important individuals in the British dye industry. He was constantly called upon for advice and developed skills as an expert witness in cases of litigation.

In late 1866 Caro decided to return to Germany. The aniline-based dyes had reached a stage of final development, and Caro's health was suffering from the foul, polluted air in Manchester that caused severe respiratory problems. The Germany that Caro returned to in 1866 was much different from the one he had left in 1859. As the authors state (p 127):

Most significant to Caro's future, and the futures of many of his colleagues, was the tremendous social and economical transformations of the country, the increasing influence of the well-educated upper middle class, the emancipation of the Jews, and the take-off of the much-delayed industrial revolution in the German states.

Much of the rest of the book addresses the question of the relationship between pure and applied chemistry, corporate structure, and innovation, as illustrated in the career of Caro. These are the types of questions that the new generation of historians have been dealing with. Earlier works such as J. J. Beer's *Emergence of the German Dye Industry* (1959) and George Meyer-Thurow's 1982 paper in *Isis*, "The Industrialization of Invention: A Case Study From the German Chemical Industry," tended to stress the importance of the advances in structural and other areas of chemistry and did not address many of the points that Reinhardt and Travis raise. The life of Heinrich Caro to them illustrates their thesis concerning the importance of these other factors.

When Caro returned to Germany, he first settled in Berlin but then moved to Heidelberg for reasons of health and was admitted to the laboratory of Robert Bunsen. Caro, at this point, entertained the idea of an academic career while perhaps acting as a consultant to the emerging German dye industry. At Heidelberg he pursued his investigations into rosolic acid, which he had begun in Manchester. This research would later lead to a synthesis of alizarin, the red dye derived from the madder plant.

Caro was invited in 1867 by the founders of BASF to act as an external inventor and consultant for their new plant at Ludwigshafen in Bavaria. BASF manufactured both inorganic bulk chemicals and aniline dyes at Ludwigshafen, where the "wide, fast-flowing Rhine was used for water disposal, particularly the mixture of aromatic and arsenic compounds employed in the production of aniline dyes." (p 112).

Before Caro's association with BASF, the German dye industry had relied on pirating the products of other manufacturers. Patents were virtually worthless in the various parts of the still fragmented Germany. Basic research to produce new inventions was not done, and this would be the greatest impact that Caro would have. He negotiated a profit sharing arrangement with BASF for the recipes to make three of the dyes he had invented. In contrast to other consultants who moved from one job to another, Caro stayed with BASF and in November, 1868 became the joint managing technical director. The authors cite the terms of the contract to show that here is the first example of a technical director who also had a research function.

Mr. H. Caro is to undertake, in particular, tasks in the laboratory that are necessary from both a theoretical and practical point of view. (p. 138). With this document, science-based industry had been formalized.

Caro's first major achievement at BASF was the production of synthetic alizarin by using the laboratory process developed by the academic chemists Carl Graebe and Carl Lieberman, assistants to Adolf Baeyer at the Gewerbeakademie in Berlin. Caro made significant contributions to the transfer of this laboratory synthesis to a commercial product. The difficulties encountered in the scaling up are discussed in great detail as well as the contributions made by William Henry Perkin, who shared alizarin production with BASF. Perkin had developed a process similar to that of Caro, Graebe, and Lieberman; but theirs had been patented in London first. The industrial alizarin synthesis marked the beginning of the application of the structure of organic molecules as a means of rational synthesis, and the collaboration between academics and industrialists. From this time on, Caro was to make the fullest use of academic-industrial connections for the benefit of BASF.

After 1877 azo dyes became increasingly important, and by 1900 the greatest number of dyes were members of this class. The diazotization and coupling reaction was first discovered by Peter Griess, one of Hofmann's assistants in London in 1858. The authors discuss the various types of azo dyes as well as the contributions made by Caro, Griess, Martius, Witt, and Hofmann.

A single chapter is devoted to one of Caro's major achievements, the fostering of the academic–industrial collaboration. The BASF model would be replicated by many of the other German dye companies; in many ways it was the industrial research that drove the academic research agenda in the nineteenth century. The close collaboration between Caro and Adolf von Baeyer is discussed in great detail as a means of showing the growing partnership of academia and industry. Baeyer worked closely with Caro from 1873-1883 when BASF, deciding to establish its own central research laboratory, greatly reduced its dependence on external contract consultants. Caro supplied Baeyer with technical and patent information as well as organic chemicals. Baeyer in turn reported his discoveries to Caro and undertook the analysis and structural elucidation of industrial products and intermediates. They published jointly and each greatly admired the other's type of work. The most important product of this collaboration was synthetic indigo, which was not marketed until 1897. Without the encouragement of Caro the authors contend that synthetic indigo would not have been produced. At least ten other academic chemists, including Emil Fischer and Victor Meyer, acted as consultants on a continuous basis for BASF in this period of time.

By 1885 the BASF management had decided to centralize its discovery of new products in house and it was Caro who created the model of the industrial research laboratory. "The modern, dedicated, industrial research laboratory, and in particular the central research laboratory was an organizational innovation in its own right and by 1900 an important component of all leading science-based dye firms."(p 220). The German model was not duplicated in France or Britain. This has often been cited as one of the reasons for the failure of the chemical industries in these countries and their dependence on German imports.

The historical development of the BASF central laboratory under the direction of Caro is discussed in great detail. The authors meticulously describe the organization and the types of research conducted. When Caro retired from BASF in 1890, the circumstances were a subject of much speculation. Caro felt that he had not been able to accomplish all he had set out to do. He advised his close friend Ivan Levinstein, "I am starting on a new way of life, because the former one has led me on to fruitless and desolate fields of work." (p 306). Caro continued to consult for BASF but did not produce any new marketable products.

In retirement Caro became a chemical celebrity and was much admired, particularly in England, for his pioneering industrial research. He began writing a history of the dye industry soon after his retirement, which was published in the *Berichte der Deutschen Chemischen Gesellschaft* in 1892. Caro became chairman of the *Verein Deutscher Chemiker* in 1897 and held the post until 1901. His management of the society led to a doubling of its membership, and it became the most important chemical society in Germany. Caro was also responsible for improving the society's journal, *Zeitschrift fur Angewandte Chemie*. He was the German coordinator for the 50th anniversary celebrations of the discovery of mauve held during July, 1906 in London. He greatly enjoyed seeing his old friends from the beginnings of the synthetic dye industry again. Caro, who had suffered from poor health his whole life, finally succumbed on September 11, 1910, at age 76.

In a final chapter the authors discuss the myths that developed concerning Heinrich Caro after his death. In Great Britain, which had been the birthplace of the dye industry, the departure of Caro, Hofmann, and other German chemists in the 1860s was given as one reason, in the early part of the 20th century, when attempts were being made to rationalize the failure of the British dye industry. This was not the only reason, but when included with the lack of investment in research by the British dye industry, the fundamental lack of appreciation of the theoretical developments in aromatic chemistry, and an antiquated educational system, they all contributed to the collapse of the British dye manufacture.

Caro, it is pointed out by the authors, had his faults, particularly a quarrelsome nature with his colleagues, which made him less than the most successful of leaders. However, being first in the introduction of so many new dyes and cultivating a system of close and fruitful contacts with academic chemists, he attained a nearly mythic status.

Through the story of Heinrich Caro, Reinhardt and Travis have produced the definitive work on the early years of the synthetic organic chemical industry. The foundations that Caro laid down flourished and endured, evolving smoothly from dyestuffs to pharmaceuticals and explosives, then to high-pressure chemistry, synthetic polymers, and, finally, the life sciences. My only regret is that the price of this book will discourage its wide distribution. *Martin D. Saltzman, Providence College, Providence, RI 02918.*

***Erratum*:**

Volume 27, Number 2, p 108:

Legend under the photograph should read:
"Francis Home, courtesy the Wellcome Trust"