Some Late 19th- and Early 20th-Century American Historians of Chemistry

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Introduction

Beginning with the late 18th-century works by Wiegleb and Gmelin, European chemists had, by the end of the 19th century, generated an impressive literature dealing with the history of chemistry and alchemy (1). However, with the exception of the late 19th-century histories by Ernst von Meyer (2) and Alfred Ladenburg (3), virtually none of this treasure trove has ever been translated into English. In sharp contrast, American chemists were, with few exceptions, quite late in entering this field and it is the intent of this paper to remind the present generation of American chemical historians of some of their early predecessors by providing a brief overview of their lives and contributions to the history of chemistry.

Henry Carrington Bolton

Henry Carrington Bolton (figure 1) was born on 28 January 1843 in New York City, the only child of Jackson Bolton, a successful physician, and Anna Hinman North. (4-6). He received his elementary and secondary education in private schools, followed by an undergraduate degree at age 19 from Columbia University, where he studied chemistry under Charles A. Joy. Bolton then began a five-year period of travel and graduate work in Europe, including time at Paris with Dumas and Wurtz; at Heidelberg with Bunsen, Kopp, and Kirchoff; at Berlin with Hofmann; and at Göttingen with Wöhler. In 1866 he received his doctoral degree from the latter institution for a thesis on the fluorides of uranium (7).

After returning to the United States in 1868, Bolton opened a private laboratory in New York City, where he accepted a few students for private instruction. Four years later he was offered a position teaching quantitative analysis at the Columbia School of Mines, which he resigned in 1875 to teach chemistry at the Woman's Medical College of the New York Infirmary, followed in 1877 by his appointment as Professor of Chemistry at Trinity College in Hartford, Connecticut.

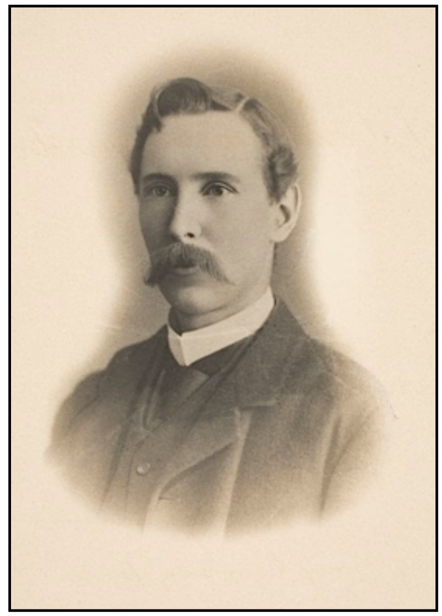

Figure 1. Henry Carrington Bolton (1843-1903)

Reading between the lines of his various biographical sketches, it is apparent that Bolton came from a financially well-to-do family. His father had died in 1866 and, with the death of his mother in 1887, Bolton was able to resign his position at Trinity and live on his inheritance for the remainder of his life. He died in his home in Washington DC on 19 November 1903 at the premature age of 60.

Pratt estimates that Bolton published more than 300 papers, notes, and books during his brief life and it is obviously impossible to provide a critical survey of his entire *oeuvre* within the confines of this paper (6). His early chemical work was largely published in Charles Chandler's *American Chemist* and, after its demise in 1877, in a variety of journals, such as *The Chemical News* and the *Annals of the New York Academy of Sciences*. It dealt mostly with the minutiae of teaching analytical chemistry, the chemistry of uranium (as per his doctoral thesis), and with the use of dry organic acids, rather than liquid mineral acids, in the field analysis of minerals. During his tenure at Trinity College he also published a textbook on qualitative analysis, which went through several reprintings (8).

Bolton's interest in bibliography also began quite early when he published a bibliography dealing with the chemistry of uranium in the 1870 volume of Chandler's journal and, between 1873-1877, a multipart series dealing with early American chemical literature. This was followed in 1885 by his "Catalogue of Chemical Periodicals" (9) and his massive *Catalogue of Scientific and Technical Periodicals, 1665-1882*, which was further expanded in 1897 (10). 1893 saw the publication of what most historians of chemistry consider his magnum opus, *A Select Bibliography of Chemistry, 1492-1892*, followed by two large supplementary volumes in 1899 and 1904 (11). In connection with this work he also became a discriminating collector of historically important books on chemistry and alchemy and his wonderful personal library was well known among his friends and colleagues.

Publication of Bolton's many articles on the history of chemistry also began in 1870 with the appearance of one of my favorites, "Historical Notes on the Defunct Elements" (12) – a theme that has more recently been expanded into a large book (13). Also of note are several later articles on the history of early chemical societies (14, 15). Though he never seems to have been tempted to write a history of chemistry, in 1892 Bolton was appointed as "Nonresident Lecturer on the History Chemistry" at Washington University in St. Louis, in which capacity he taught a course in that subject, and he received a similar one-year appointment at Columbia University the following year. Both appear to have been one-shot deals and were never repeated.

In 1874 Bolton published a letter suggesting that American chemists should celebrate the centennial of Joseph Priestley's discovery of oxygen (16). This led, in turn, to the famous gathering of American chemists at the Priestley house in Northumberland, Pennsylvania, later that year, and ultimately to the founding of the American Chemical Society (17). Having met many of Priestley's descendants at that gathering, Bolton was able to acquire a collection of Priestley letters in their possession. These he eventually combined with several articles he had written on Priestley into a book that he privately published in 1893 (18). In 1900 he published a small volume on the history of the thermometer (19), and in 1904 a collection of articles he had written for the *Pharmaceutical Review* on alchemy and pseudoscience in the 16th-century court of Rudolf II of Bohemia was published posthumously (20).

In addition to his chemical, bibliographical, and historical publications, Bolton also published on a bewildering variety of other topics, in an equally bewildering variety of magazines and journals, ranging from magic squares and singing sands, to the vocabulary used by people when talking to animals. He also published a volume on family genealogy (21) and one on childrens' counting-out rhymes (22). However, it must be said that, while Bolton's articles and books, whatever their subject, are always interesting and entertaining, there is always something of the antiquarian rather than the polished historian about his writing, dealing, as it often does, with the curious and unusual rather than with broad historical trends and significant themes.

An eminently "clubbable" man, Bolton was reputed to have belonged to more organizations than any other American of his generation. These included not only professional societies, but social clubs – many of which he was the founder. This propensity for male social interaction is probably explained by the fact that Bolton remained a bachelor until age 50, when he married one Henrietta Irving of Brighton, New York, who was destined to outlive him by some 27 years. After his death, she disposed of his prize book and journal collection and some 160 engraved portraits of famous scientists by giving them to the Library of Congress. However, recent inquiries indicate that they have since been either dispersed or disposed of and can no longer be traced (6).

Francis Preston Venable

Francis Preston Venable (figure 2) was born on 17 No-

Figure 2. Francis Preston Venable (1856-1934)

vember 1856 near Farmville, Virginia, the son of Charles Scott Venable and Margaret Cantey McDowell (23-25). His father was a professor of mathematics at several southern colleges and universities and had served as an *aide de camp* to General Lee during the American Civil War. Receiving his undergraduate training at the University of Virginia, where his father was then teaching, Venable taught high school for a year in New Orleans after graduating in 1877. He then embarked on graduate work in chemistry, first at the University of Virginia, and then at the University of Bonn. In 1880, while still at Bonn, he was appointed Professor of Chemistry at the University of North Carolina in Chapel Hill. After checking in at Chapel Hill, Venable returned once more to Germany in order to complete his graduate studies, finally receiving his doctoral degree from the University of Göttingen in 1881 for a thesis on heptane (26).

Venable would spend much of his academic career in administration, serving as Head of the Chemistry Department from 1880-1900, as President of the University of North Carolina from 1900-1914, and as department head once more from 1917-1921. He also served as President of the American Chemical Society for 1905. He finally retired in 1930, after 50 years of service, and died four years later on 17 March 1934 at age 78.

Throughout his career Venable would publish many research articles in the field of inorganic chemistry, as well as textbooks on qualitative analysis (27) and descriptive inorganic chemistry (28). His final book was an advanced monograph on the chemistry of zirconium, upon which he was considered an authority (29). His most significant contribution, however, was his involvement in the development of an inexpensive process for the production of calcium carbide, which would give rise to an important local chemical industry and eventually lead to the founding of Union Carbide.

In 1894 Venable published *A Short History of Chemistry* (30). This may well be the first published American textbook on the general history of chemistry, and was written for use in a history of chemistry course that Venable taught at North Carolina – a fact which kept it in print at least through the 1920s. The operative word in its title is "Short," since it was only 163 pages long and is little more than an annotated chronology, with many topics, each of which is highlighted in bold print, being covered in a single paragraph or less.

Venable would later author two more works of interest to historians of chemistry: his 1896 monograph on *The Development of the Periodic Law* (31) and his 1904 monograph on *The Study of the Atom or The Foundations of Chemistry* (32). Though almost certainly intended as contributions to the advanced research literature when they were first written, both books are now most valued by historians. This is especially true of the volume on the periodic law because of the large number of engravings of early periodic tables used as illustrations. Like his earlier history of chemistry, both books are written as annotated chronological summaries – a writing style which gives them a somewhat disjointed feel. To this list one might add a small 1917 booklet entitled *A Brief Account of Radioactivity* (33), though this is lacking the detailed coverage of the previous two books.

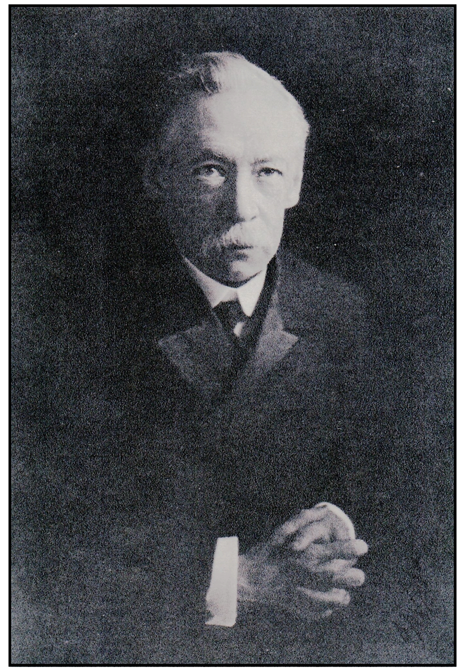

Figure 3. John Maxson Stillman (1852-1923)

John Maxson Stillman

John Maxson Stillman (figure 3) was born on 14 April 1852 in New York City, the son of Jacob Stillman and Caroline B. Maxson (34-36). His father was a successful physician and author of a well-known monograph on *The Horse in Motion*. His mother having died a few months after his birth, Stillman was left in the care of his maternal grandparents until the age of nine, when he joined his father and his second wife in Sacramento. A year later the reunited family moved to San Francisco, where Stillman completed his elementary and secondary education, before entering the University of California in 1870.

After graduation in 1874 and a year of graduate research at his *alma mater*, he spent a year studying organic chemistry at the Universities of Strassburg and

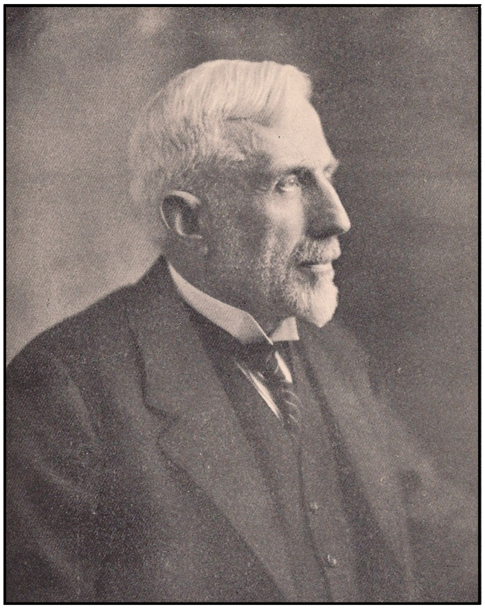

Figure 4. Forris Jewett Moore
(1867-1926)

Würzburg. Leaving without a degree, he returned to California in 1876, where he served as an instructor in organic and general chemistry for the next six years at the University of California-Berkeley, during which time he also published nine papers dealing largely with the chemical characterization of the resins and oils of native California plants.

In 1882 he accepted a position in industry as Chief Chemist and Superintendent of the Boston and American Sugar Refining Company, where he remained until 1891, when he received an invitation to serve as executive head of the chemistry department for the newly organized Stanford University, a position which he held until his retirement in 1917. Beginning in 1913 Stillman also served as Vice President of Stanford and, in this capacity, often as the acting president.

In 1885, during his time in Boston, Stillman was awarded an external doctoral degree from his *alma mater* for his published research, and an honorary LL.D degree from the same institution the year before his retirement. He would pass away suddenly from a stroke on 13 December 1923 at age 71. A discriminating collector of art in his later years, he particularly favored Japanese prints and carvings.

Stanford University had offered a course in the history of chemistry since day one and in 1902 Stillman was given a chance to teach the course when the original instructor passed away. It was, however, not until 1912 that he began publishing articles on the history of chemistry. Indeed, he would publish only ten during the remaining decade of his life, largely in the journals *Scientific Monthly* and *The Monist*, and mostly dealing with alchemy and iatrochemistry (37). These were prompted by his attempt to clarify certain topics for his history of chemistry course, and in 1920 those dealing with the Swiss/German iatrochemist, Paracelsus, were collected together in the form of a small biographical monograph (38).

In 1923 he published his magnum opus, *The Story of Early Chemistry,* a carefully researched 566-page history of chemistry from its first beginnings through the 18th century (39). Properly documented and scholarly, yet written in an unpretentious and readable style, this book provided American and British readers with some of the only English-language summaries of the work of such important European scholars as Kopp, von Lippmann, and Berthelot, and received great praise from its reviewers, whether chemists or professional historians. In 1960 the book was reprinted under the revised title of *The Story of Alchemy and Early Chemistry* by Dover Books (40) and it remains today as one of the best and most authoritative books ever produced by an American historian of chemistry.

Forris Jewett Moore

Forris Jewett Moore (figure 4) was born on 09 June 1867 in Pittsfield, Massachusetts, the son of Forris J. Moore Sr. and Ellen S. Wrightman (41, 42). His father having died shortly after his birth, Moore was raised in the home of an uncle in Claremont, New Hampshire, where he received his elementary and secondary education. In 1885 he entered Amherst College. There he studied chemistry under Elijah P. Harris, remaining for a year after graduation in 1889 in order to serve as Harris' teaching assistant. In 1890 Moore departed for Heidelberg, where he studied organic chemistry under Ludwig Gattermann and Victor Meyer, receiving his doctoral degree in 1893 for a thesis on the isolation of aromatic sulfonic acids (43). While at Heidelberg he met a young girl from Scotland by the name of Emma Todd, who was there studying music and German, and whom he would marry in 1892.

Upon his return to the United States, Moore served for a year as an instructor in chemistry at Cornell University before accepting a position in analytical chemistry at MIT, where he would remain until his early retirement in 1925 due to complications from heart disease, followed by his premature death a year later on 20 November 1926 at age 59. Though initially hired as an analytical chemist, starting around 1902 he became increasingly involved in the teaching of organic chemistry – a field in which he would publish some 18 research papers, as well as both a textbook (44) and laboratory manual (45).

Moore's history of chemistry was first published in 1918 as part of McGraw-Hill's International Chemical Series and was the product of his having given a senior seminar on "the fundamental ideas of science: their origin, their philosophical basis, the critical periods in their development, and the personalities of the great men whose efforts have contributed to that development" (46). The result was a 292-page textbook on the general history of chemistry that would soon eclipse the slim outline provided earlier by Venable.

In a sense this contribution came out of the blue, since Moore had never published articles on the history of chemistry prior to the appearance of his book, nor would he subsequently. After his death, the book would be expanded and revised by William T. Hall, also of MIT, first in 1931 and again in 1939. Though based largely on the secondary European literature, this volume would, nevertheless, remain the sole serious American textbook on this subject until the 1950s (47) – a situation that contrasts sharply with the plethora of English-language histories produced by British chemists during this same period, including those by Armitage (1906), Pattison-Muir (1909), Thorpe (1909), Hilditch (1912), Brown (1913), Lowry (1915), Masson (1925), Holmyard (1931), and Partington (1939).

A few years after Moore's death his widow endowed several student fellowships in his name at both Harvard, where he had occasionally guest lectured, and at Amherst, as well as a fund for expanding a collection of portraits of famous chemists on display in the hallways of the chemistry department at MIT. This collection was placed under the management of Henry Monmouth Smith, who would reproduce the portraits in a 1949 volume entitled *Torchbearers of Chemistry* (48). However, when I inquired in 2009 as to the current status of this collection, I was informed that all traces of the 250 portraits had vanished, including a one-of-kind oil painting by the 19th-century American artist, Anna Lea, commemorating the discovery of synthetic alizarin (49, 50).

Figure 5. Edgar Fahs Smith (1854-1928)

Edgar Fahs Smith

Edgar Fahs Smith (figure 5) was born on 23 May 1854 near York, Pennsylvania, the eldest of two sons of Gibson Smith, the owner of a local grist mill, and Elizabeth Fahs (51-53). He was educated at the York County Academy and at Pennsylvania College of Gettysburg, where he was influenced to pursue a career in chemistry by Samuel Sadtler. After graduation in 1874, he spent two years at Göttingen University in Germany, from which he received his doctoral degree in 1876 for a thesis on trisubstituted benzene compounds and the reaction between chlorine and benzyl trichloride (54). Despite Smith's later insistence that Wöhler had been his thesis advisor, the actual thesis assigns that role instead to Wöhler's assistant, Hans Hübner.

Upon his return from Germany, Smith took a position for five years as an assistant in analytical chemistry at the University of Pennsylvania. From 1881-1888, he held a series of short-lived appointments, first at Muldenberg College in Allentown, PA, and then at Wittenberg College in Springfield, OH. Finally, in 1889 he returned once more to the University of Pennsylvania as Professor of Analytical Chemistry, where he specialized in electro-gravimetric analysis. In 1892 Smith became department head and in 1898 vice provost of the university, followed by his appointment as provost in 1904 – a position he would hold until his retirement in 1920. He also served as President of the ACS three times (1895, 1920, 1921). He would pass away after eight years of retirement on 03 May 1928 at age 73.

Miles estimates that during his career Smith published more than 169 articles in the research literature, as well as supervising the theses of 87 doctoral students (51). Between 1878 and 1907 he translated at least five German textbooks dealing with such diverse subjects as analytical chemistry (55), electrochemistry (56, 57), organic chemistry (58), and inorganic chemistry (59), and published at least three of his own dealing with urine analysis (60), general chemistry (61), and electro-gravimetric analysis (62). To this list one might add a small monograph on the atomic weights of boron and fluorine published in 1918 (63).

Though Miles claims that Smith's interest in history of chemistry went back to the start of his career in the 1870s (51), it was not until 1913 that he published his first book on the subject (64). Unfortunately, the precise purpose of this volume is ambiguous to say the least. Entitled *The Theories of Chemistry*, it was ostensibly a series of lectures for a course on theoretical chemistry, but was heavily historical in its approach. Like the 1883 textbook on the same subject by Ira Remsen (65), it focused almost exclusively on the history of the struggle to establish a self-consistent set of atomic weights and the resulting consequences for the determination of reliable compositional and structural formulas. Neither book makes mention of either chemical thermodynamics or kinetics, though Smith, being an electrochemist, does conclude with a brief account of the ionic theory of dissociation. As we will see, like most of Smith's other books, there were almost no references and the coverage of many topics was quite superficial.

The next year Smith published his most important historical work, a 356-page explicit history entitled *Chemistry in America* (66). This would establish the tenor of all of his subsequent books, which dealt exclusively with biographies of early American chemists and were essentially elaborations of subjects found in his 1914 overview history. These elaborations began in 1917 with a massive 508-page biography of Robert Hare (67), followed the next year by a smaller format 299-page biography of James Woodhouse (68), followed the next year by a 106-page account of various early chemists of Philadelphia (69) and a 94-page biography of James Cutbush (70). They ended in 1920 with a small format 173-page account of Joseph Priestley's time in America (71). During his retirement years Smith also self-published a series of biographical pamphlets of between 10 and 27 pages, each dealing with yet other early American chemists that I have not explicitly listed in the references, since most of them were also reprinted as articles in the *Journal of Chemical Education*.

Indeed, I strongly suspect that the majority of Smith's books on the history of chemistry were so-called "vanity" publications. It was a standard practice of established publishers to print such books subject to the condition that the author would agree to purchase several hundred copies on his own in order to cover the publication costs. This would account for the fact that piles of pristine copies of Smith's books were still to be found in the Smith Collections at the University of Pennsylvania in the 1970s when the Center for the History of Chemistry was housed there.

Given the enormous literature eulogizing Smith as the so-called founding father of history of chemistry in the United States, I feel like something of a traitor to report that, having read his historical books, I find most of them to vary between the mediocre and the terrible. As already noted, they lack proper referencing and context, and he often, for lack of more substantive biographical material, unnecessarily pads them with verbatim reproductions of entire technical papers, booklets, or mundane letters devoid of biographical interest. He frequently vastly overstates the importance of his subject's contributions to chemistry, and often breaks into sonorous eulogistic phrases more suitable for a memorial oration than a critical biographical account. Most of the subjects covered by Smith have subsequently been treated in a more historically acceptable and balanced manner in the writings of the late Wyndham Miles (72).

Smith's emphasis on the biographies of early American chemists is ultimately traceable to his interest in collecting early chemistry textbooks, and especially those having American authors or editors. Just as Bolton's writings have more of the antiquarian than the historian about them, so Smith's writings have more of the collector than the historian about them, and can be viewed as his way of annotating his treasured collections – a motive made most explicit in his final book on *Old Chemistries* (73).

Smith's private collections did not meet the same fate as those of Bolton and Moore, since, after his death, the University of Pennsylvania decided to preserve them as a memorial to his name. At the time they included some 3000 books, 600 manuscripts and 1800 images and were located in his office in Harrison Hall (74). When this building was torn down, the collections were transferred to a suite of rooms in the new university library, where they remain to this day, having now been expanded to include some 15,000 books and journals, 100 linear feet of manuscripts, and 4000 images (75). Officially known as "The Edgar Fahs Smith Memorial Collection in the History of Chemistry," this legacy, far more than his various books, is now considered his most important contribution to the history of chemistry (76).

Arthur John Hopkins

Arthur John Hopkins (figure 6) was born on 20 September 1864 in Bridgewater, MA, the youngest of two sons of Lewis S. Hopkins, a medical doctor, and Fanny J. Washburn (77). After graduation from Bridgewater High School, he attended Amherst College, from which he received his undergraduate degree in chemistry in 1885. Following a series of short-lived jobs, including

Figure 6. Arthur John Hopkins
(1864 -1939)

serving as a high school principal (1886-1888) in Cotuit, MA, and teaching science (1888-1890) at the Peekskill Military Academy in Peekskill, NY, he entered graduate school at Johns Hopkins University in Baltimore, from which he received his doctoral degree in 1893 for a thesis done under Professor Harmen N. Morse (1848-1920) on *The Reaction Between Manganese Dioxide and Potassium Permanganate* (78). It was during his graduate school days that Hopkins also met a local Baltimore girl and authoress by the name of Margaret Sutton Briscoe, whom he would marry in 1895.

With his freshly minted Ph.D, Hopkins was able to land a job at Westminster College in New Wilmington, PA, followed within a year by an instructorship at his undergraduate *alma mater*. In 1907 he was promoted to full professor and became Elijah P. Harris' successor as department head – a position that he would hold until his own retirement in September of 1934, after 40 years of teaching at Amherst.

His retirement years were busy. An avid mountain climber and sailing boat enthusiast, he would help lay out hiking paths to the peaks of many of the mountains in the Holyoke range, would construct an observation tower on top of Mt. Toby, and would write an unpublished manual advocating a decimal system for sail boat navigation, as well as publish his magnum opus on the origins of alchemy (see below). He would finally pass away on 10 November 1939 at age 75. Having requested cremation rather than burial, his ashes were scattered among the hills of his beloved Holyoke range.

As might be anticipated for a teacher at a small undergraduate college in the years before the ACS began to emphasize the importance of undergraduate research, Hopkins' publication record in chemistry was scant and included only nine papers and notes. With the exception of a long paper on the periodicity of the specific gravities of the elements published in 1911 (79), most of these are of little interest today and largely deal with issues related to the teaching of undergraduate chemistry, such as the use of nichrome gauze, the standardization of balance weights, and the calculations used in quantitative analysis.

If Hopkins' chemical work was unremarkable, the same cannot be said of his work in history of chemistry. This began in 1902 with the publication of an article in the 31 January issue of *The Chemical News* entitled "Bronzing Methods in the Alchemistic Leyden Papyri" (80). In this paper Hopkins noted the similarity between various recipes in the 3rd-4th century Leyden X papyrus and the recipes for coloring metal surfaces found in a recently published book on the bronzing of metals by the British chemist Alexander Hiorne (81). This led him to propose two working assumptions :

1st. The Egyptian worker in metal was a bronzer.

2nd. Gold or silver was identified, not only by the color of the metal, but also by the bronze that could be produced upon it.

He then used these assumptions to clarify several ambiguous recipes in Marcellin Berthelot's recent French translation of the Greek in which the Leyden papyrus was originally written.

The term bronzing, when used in conjunction with metals, is a rather loose term for any process used to impart color to the metal's surface, including dipping in various chemical baths (often followed by heating), exposure to chemical vapors, use of lacquers or other coatings containing powdered metals, or electroplating. Obviously Hopkins was interested in the first two procedures. These can alter the color of the metal surface by leaving a colored chemical deposit of some sort, or by leaving a thin film of either the metal oxide or sulfide. Depending on the thickness of this film, an entire spectrum of colors can be produced due to interference between the reflected and transmitted light rays. The same phenomenon is responsible for the colors observed when a thin film of oil floats on water or when two glass plates are pressed together. Known as Newton's rings, calculation of the wavelengths of the resulting colors as a function of the thickness of the oxide, sulfide or oil film, or of the air space between the glass plates, is an exercise in most introductory college physics courses.

Hopkins also proposed two further hypotheses that he would expand upon in his later writings. The first of these was that the ancient Egyptians were, because of their drab desert environment, "color hungry" :

The Egyptian longed for the golden sun color with which to adorn his temples, and metallic colors were both brilliant and permanent. Brilliant colors, and, if possible, permanent colors, the child nations of the world have always delighted in. Gold, silver, purple, and (in Egypt) black are the delights of kings and peoples.

The second was that the coloring of metal surfaces through the use of bronzing or pickling baths was based on an analogy with the dyeing of cloth and the use of mordants:

Historically it is evident that the original artisan of our our papyri was a dyer in purple, for Papyrus X ends with recipes for dying, and the writings of the pseudo - Democritus are prefaced by two careful recipes for dyeing in purple. Also the dyer evidently transferred his dyeing methods to his new business as a worker in metals, for many of the recipes for producing metals of a golden color strikingly resemble the methods of dyeing.

He also briefly hinted that the order of surface colors obtained in the bronzing process for metals was later perverted by European alchemists into the color sequence required to produce the so-called philosopher's stone:

black → white → yellow → red or violet (Ios)

Sixteen years would pass before Hopkins once again returned to the subject of alchemy, this time with a popular article in the *Scientific Monthly* (82). Less encumbered by the detailed discussions of imperfectly translated recipes from the Leyden papyrus, this paper contained much clearer statements of Hopkins' evolving assumptions concerning the nature of Greco-Egyptian alchemy. The most important of these was that he now believed that Greco-Egyptian alchemy had never concerned itself with a literal material transmutation of base metals into actual gold, but rather only with a "color transmutation," leading to the bronzing of various metals and alloys with a golden color or, better yet, a violet color known in Greek as *Ios*.

He now also believed that philosophers had become interested in Egyptian bronzing techniques because they viewed them as a literal experimental test of Aristotle's doctrine of form and matter, i.e. of the ability to strip a piece of matter of its previous qualities and to impose new ones – the quality in question being, of course, its color. In this article he further expanded upon his earlier passing suggestion that, by the time alchemy reached Europe in the 12th century, these doctrines were so muddled that European alchemists would incorrectly interpret them as a literal transmutation of base metals into true gold, rather than as the imposition of a gold color. In other words, they would pass over that thin line that separates, in the later terminology of Needham, the practice of *aurifiction* from that of *aurifaction*. For this reason, Hopkins now insisted on referring to these later confused alchemists as "pseudo- alchemists."

As early as 1920 Hopkins began writing a general history of western alchemy which was finally published by Columbia University Press in 1934 under the title of *Alchemy: Child of Greek Philosophy* (83). In the broadest terms, Hopkins divided his book into successive treatments of Greco-Egyptian, Islamic, and European alchemy, each separated from its successor by a chapter on the transitional period, and the whole followed by concluding chapters on the eventual demise of alchemy in the 18th century. Not surprisingly, his beloved color theory of Greco-Egyptian alchemy was given pride of place, with Islamic and European alchemy receiving lesser, but adequate, coverage. In keeping with the author's decision to restrict the book to a history of western alchemy, virtually no mention was made of either Chinese or Indian alchemy.

In general the book, which was reviewed by both chemical and classical journals, received a favorable response and was reprinted in 1967. To the best of my knowledge, no one has yet refuted Hopkins' color theory of the origins of Greco-Egyptian alchemy and, if Stillman's book remains the most scholarly work produced by the first generation of American chemical historians, then surely Hopkins' modest volume remains the most original.

Conclusions

With the publication of Hopkins' book in 1934 and his death in 1939, we see the passing of the last of what I have just referred to as "the first generation" of American chemical historians. The next generation, though overlapping with the first throughout the 1930s, would remain active through the end of the 1940s and would include such names Charles A. Browne Jr. (84) and Tenney Lombard Davis (85). Though the first generation was responsible for the founding of the ACS Division for the History of Chemistry in 1921, it is the second generation that would see the founding of *Chymia* in 1948, the first American journal devoted exclusively to the history of chemistry. In the 1950s this second generation was succeeded, in turn, by such historians as

Herbert Klickstein, Henry Leicester, and Eduard Farber, and they would witness the establishment of the Dexter Award for Outstanding Achievement in the History of Chemistry in 1956. This era would culminate a little past midcentury with with the publication of Aaron Ihde's epic *Development of Modern Chemistry i*n 1964 (86), which still remains the most comprehensive American textbook dealing with the general history of chemistry published to date.

References and Notes

1. For an overview of this European literature, see J. Weyer, *Chemiegeschichtsschriebung von Wiegleb (1770) bis Partington (1970)*, Gerstenberg: Hildescheim, 1974.

2. E. von Meyer, *A History of Chemistry*, Macmillan: London, 1891; 2nd ed., 1898; 3rd ed., 1906.

3. A. Ladenburg, *Lectures on the History of Chemistry Since the Time of Lavoisier*, Alembic Club: Edinburgh, 1905.

4. Anon., "Sketch of Henry Carrington Bolton," *Pop. Sci. Monthly,* **1893**, *43*, 688-695.

5. C. A. Browne, "Henry Carrington Bolton," *J. Chem. Educ*., **1940**, *17*, 457-461.

6. H. T. Pratt, "Henry Carrington Bolton," A Truly Renaissance Man," *Boltonia*, **2004**, *6*, 2-5.

7. H. C. Bolton, *On the Fluorine Compounds of Uranium*, Ph.D. Thesis, University of Göttingen, 1866. Original title and thesis in English.

8. H. C. Bolton, *Student's Guide to Qualitative Analysis*, Wiley: New York, NY, 1882, 3rd ed., 1889.

9. H. C. Bolton, "A Catalogue of Chemical Periodicals," *Ann. N. Y. Acad. Sci*., **1885**, *3*, 159-213.

10. H. C. Bolton, *A Catalogue of Scientific and Technical Periodicals, 1665-1882*, Smithsonian: Washington, DC. 1885. Expanded second edition, 1897.

11. H. C. Bolton, *A Select Bibliography of Chemistry, 1492-1892*, Smithsonian, Washington, DC, 1893; First Supplement, 1899; Second Supplement, 1904.

12. H. C. Bolton, "Historical Notes on the Defunct Elements," *Amer. Chemist*, **1870/1871**, *1*, 1-3

13. M. Fontani, M. Costa, M. V. Orna, *The Lost Elements: the Periodic Table's Shadow Side*, Oxford University Press: New York, NY, 2015.

14. H. C. Bolton, "Early American Chemical Societies," *J. Am. Chem. Soc*., **1897**, *19*, 717-732.

15. H. C. Bolton, "Chemical Societies of the Nineteenth Century," *Smithsonian Misc. Publ.,* **1902**, *41*, 1-15.

16. H. C. Bolton, "Centennial of Chemistry, 1774-1874," *Amer. Chemist*, **1873/1874**, *4*, 362.

17. S. A. Goldschmidt, "The Birth of the American Chemical Society at the Priestley House in 1874," *J. Chem. Educ*., **1927**, *4*, 145-149.

18. H. C. Bolton, *Scientific Correspondence of Joseph Priestley*, Collins: Philadelphia, 1892.

19. H. C. Bolton, *Evolution of the Thermometer, 1592-1743*, Chemical Publishing Co: Easton, PA, 1900.

20. H. C. Bolton, *The Follies of Science in the Court of Rudolf II, 1576-1612*, Pharmaceutical Review Co: Milwaukee, WI, 1904.

21. H. C. Bolton, *The Family of Bolton in England and America, 1100-1894*, Tuttle, Morehouse and Taylor: New Haven, CT, 1895.

22. H. C. Bolton, *The Counting-Out Rhymes of Children: Their Antiquity, Origin, and Wide Distribution. A Study in Folklore*, Appleton: New York, NY, 1888.

23. J. M. Bell, "Dr. F. P. Venable's Contributions to Chemistry," *J. Chem. Educ*., **1930**, *7*, 1300-1304.

24. M. M. Bursey, *Francis Preston Venable of the University of North Carolina*, Chapel Hill Historical Society: chapel Hill, NC, 1989.

25. M. M. Bursey, *Carolina Chemists: Sketches from Chapel Hill*, Department of Chemistry, University of North Carolina: Chapel Hill, NC, 1982.

26. F. P. Venable, *Ueber einige Derivate des Heptans aus Pinus sabiniana*, Hurth: Göttingen, 1881.

27. F. P. Venable, *A Course in Qualitative Analysis*, American Book Co: New York, NY, 1883.

28. F. P. Venable, J. L. Howe, *Inorganic Chemistry According to the Periodic Law*, Chemical Publishing Co: Easton, PA, 1898.

29. F. P. Venable, *Zirconium and Its Compound*s, Chemical Catalog Co: New York, NY, 1922.

30. F. P. Venable, *A Short History of Chemistry*, Heath: Boston, 1894. Later editions 1909, 1922.

31. F. P. Venable, *The Development of the Periodic Law*, Chemical Publishing Co: Easton, PA, 1896.

32. F. P. Venable, *The Study of the Atom or The Foundations of Chemistry*, Chemical Publishing Co: Easton, PA, 1904.

33. F. P. Venable, *A Brief Account of Radioactivity*, Heath: Boston, 1917.

34. S. W. Young, "John Maxson Stillman," *Ind. Eng. Chem*., **1923**, *15*, 1283. Reprinted as the forward to reference 39.

35. H. M. Elsey, "John Maxson Stillman as a Chemical Historian," *J. Chem. Educ*., **1929**, *6*, 466-472.

36. F. O. Koenig, "John Maxson Stillman (1852-1923)," *Isis*, **1942**, *34*, 142-146.

37. A complete list is given in reference 36.

38. J. M. Stillman, *Theophrastus Bombastus von Hohenheim, Called Paracelsus*, The Open Court: Chicago, 1920.

39. J. M. Stillman, *The Story of Early Chemistry*, Appleton: New York, NY, 1923.

40. J. M. Stillman, *The Story of Alchemy and Early Chemistry*, Dover: New York, NY, 1960.

41. See the anonymous biographical sketch in the second and third editions of reference 46.

42. R. F. Trimble, "Forris Jewett Moore," in W. D. Miles, Ed., *American Chemists and Chemical Engineer*s, ACS: Washington, DC, 1976, pp. 343-344.

43. F. J. Moore, *Ueber eine Methode zur Isolierung aromatischer sulfosäuren*, PhD Thesis, Heidelberg University: Heidelberg, 1893.

44. F. J. Moore, *Outlines of Organic Chemistry*, Wiley: New York, NY, 1910; 2nd ed., 1914; 3rd ed., 1924.

45. F. J. Moore, *Experiments in Organic Chemistry*, Wiley, New York, NY, 1911.

46. F. J. Moore, *A History of Chemistry*, McGraw-Hill: New York, NY, 1918; 2nd ed., 1931; 3rd ed., 1939.

47. I use the qualifier "serious" because there are at least two American histories that appeared between the volumes by Venable and Moore – one by W. A. Hamor that was published as volume 6 of the set *The Science-History of the Universe* (Current Literature Publishing Co: New York, NY, 1909), and one by Edgar Fahs Smith entitled *The Theories of Chemistry* (Winston: Philadelphia, 1913). Buried in a home library series of the type sold in the back of magazines and without a title suggesting that it was a history of chemistry, Hamor's volume had no impact on academic circles. For comments on the ambiguities associated with Smith's book, see below.

48. H. M. Smith, *Torchbearers of Chemistry*, Academic Press: New York, NY, 1949.

49. W. B. Jensen, "The F. J. Moore Portrait Collection," *Bull. Hist. Chem.*, **2009**, *34(7)*, 61.

50. W. B. Jensen, "The Anna Lea Painting," *Bull. Hist. Chem.*, **2010**, *35(1)*, 54-55.

51. W. D. Miles, "Edgar Fahs Smith," in W. D. Miles, Ed., *American Chemists and Chemical Engineer*s, ACS: Washington, DC, 1976, pp. 445-446.

52. G. H. Meeker, "Edgar Fahs Smith, 1854-1928," *Biog. Mem. Nat. Acad. Sci.*, **1936**, *17*, 103-149.

53. H. S. Klickstein, "Edgar Fahs Smith – His Contributions to the History of Chemistry," *Chymia*, **1959**, *5*, 11-30.

54. E. F. Smith, *Ueber Trisubstituirte Benzolverbindungen und über die Einwirkung von Chlor auf Benzyltrichorid*, PhD Thesis, University of Göttingen, 1876.

55 C. Classen, *Elementary Quantitative Analysis*, Lea: Philadelphia, PA, 1878.

56. F. Oettel, *Practical Exercises in Electrochemistry*, Blakiston, Philadelphia, PA, 1897.

57. F. Oettel, *Introduction to Electrochemical Experiments*, Blakiston, Philadelphia, PA, 1897.

58. V. von Richter, *Chemistry of the Carbon Compounds*, 2 Vols., Blakiston, Philadelphia, PA, 1899.

59. V. von Richter, *Textbook of Inorganic Chemistry*, Blakiston, Philadelphia, PA, 1900.

60. E. F. Smith, J. Marshall, *Chemical Analysis of the Urine*, Blakiston: Philadelphia, PA, 1881.

61. E. F. Smith, H. F. Keller, *Experiments Arranged for Students in General Chemistry*, Blakiston: Philadelphia, PA, 1891.

62. E. F. Smith, *Electro-analysis*, Blakiston: Philadelphia, PA, 1890, 6th ed. 1918.

63. E. F. Smith, W. K. Van Haagen, *The Atomic Weights of Born and Fluorine*, Carnegie Institution: Washington, DC, 1918.

64. E. F. Smith, *The Theories of Chemistry*, Winston: Philadelphia, PA, 1913.

65. I. Remsen, *Principles of Theoretical Chemistry*, Lea: Philadelphia, PA, 1883.

66. E. F. Smith, *Chemistry in America*, Appleton: New York, NY, 1914.

67. E. F. Smith, *Robert Hare: An American Chemist, 1781-1858*, Lippincott: Philadelphia, PA, 1917.

68. E. F. Smith, *James Woodhouse: A Pioneer in Chemistry, 1770-1809*, Winston: Philadelphia, PA, 1918.

69. E. F. Smith, *Chemistry in Old Philadelphia*, Lippincott: Philadelphia, PA, 1919.

70. E. F. Smith, *James Cutbush: An American Chemist, 1788-1923*, Lippincott: Philadelphia, PA, 1919.

71. E. F. Smith, *Priestley in America*, Blakiston: Philadelphia, PA, 1920.

72. See, for example, W. D. Miles, *American Chemists and Chemical Engineers*, ACS: Washington, DC, 1976.

73. E. F. Smith, *Old Chemistries*, McGraw-Hill: New York, NY, 1927.

74. Anon., "Dr. Smith's Office to be Preserved as a Museum," *J. Chem. Educ.*, **1928**, *5,* 923-226.

75. Anon., *Catalog of the Edgar Fahs Smith Memorial Collection in the History of Chemistry*, Edgar Fahs Smith Memorial Library: University of Pennsylvania, PA, 1960.

76. Anon., *The Edgar Fahs Smith Memorial Collection in the History of Chemistry,* The National Historic Chemical Landmark Series, ACS: Washington DC, 2000.

77. W. B. Jensen, "Arthur John Hopkins and the Color Theory of Greco-Egyptian Alchemy," in W. B. Jensen, *Collected Papers*, Vol. 4, Oesper Collections, 2017.

78. A. J. Hopkins, *The Reaction Between Manganese Dioxide and Potassium Permanganate*, Ph.D. Thesis, Johns Hopkins University: Baltimore, MD, 1893.

79. A. J. Hopkins, "The Specific Gravities of the Elements Considered in Relation to the Periodic System," *J. Am. Chem. Soc.*, **1911**, *33*, 1005-1027.

80. A. J. Hopkins, "Bronzing Methods in the Alchemistic Leyden Papyri," *Chem. News*, **1902**, *85*, 49-52.

81. A. Hiorns, *Metal Colouring and Bronzing*, Macmillan: London, 1892.

82. A. J. Hopkins, "Earliest Alchemy," *Sci. Monthly*, **1918**, *6,* 530-537.

83. A. J. Hopkins, *Alchemy: Child of Greek Philosoph*y, Columbia University Press: New York, NY, 1934. Reprinted by AMS in 1967.

84. C. K. Deischer, "A Memorial Tribute to Dr. C. A. Browne," *Chymia*, **1948**, *1*, 11-22.

85. H. M. Leicester, H, S. Klickstein, "Tenney Lombard Davis and the History of Chemistry," *Chymia*, **1950**, *3*, 1-16.

86. A. J. Ihde, *The Development of Modern Chemistry*, Harper & Row: New York, NY, 1964.