History and the Teaching of Chemistry

A Tribute to Thomas Lowry's Textbook "Historical Introduction to Chemistry"

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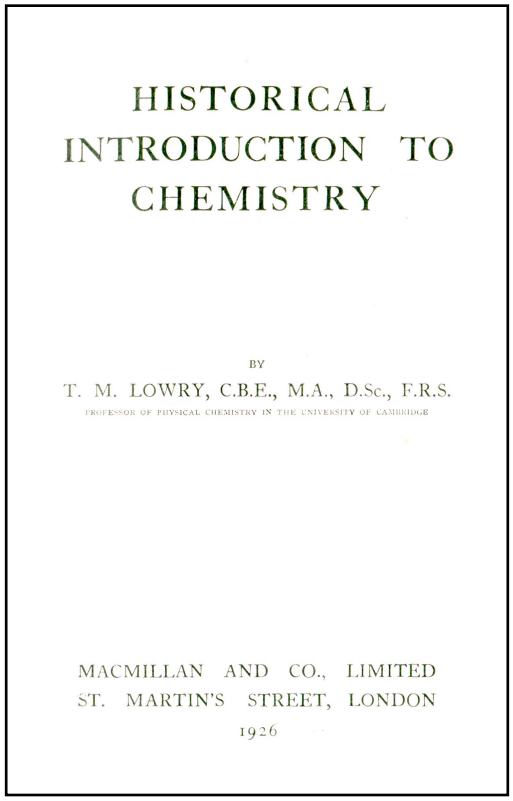
Though much has been written advocating the use of history of chemistry in the teaching of introductory chemistry courses at both the high school and college levels, there have been surprisingly few attempts to write a proper textbook based on this approach. I use the qualifying expression "proper textbook" because there are, of course many introductory textbooks which claim to include some history of chemistry, usually in the form of portraits of select chemists from the past with short biographical captions attached or, in a few cases, supplementary boxes briefly outlining the history of an important concept or discovery. Indeed, the use of portraits first became common in American textbooks starting around 1910 (1).

Unfortunately this biographical approach is subject to abuse. Early on it became a common practice to include portraits of chemists of purely secondary importance simply because their nationality happened to reflect that of the book's intended audience rather than because they had made truly important contributions to the conceptual development of chemistry (2, 3). And, more recently, this approach has become subject to increasing pressure from the political correctness movement to include chemists for reasons based on either their gender or ethnicity rather than the significance of their work.

But, more importantly, such an approach really does not use history to inform how and why certain concepts are taught in the introductory course, but rather merely serves as a sort of superficial supplement to what otherwise remains an essentially traditional approach to content – a supplement that is usually justified by the argument that it adds a "human interest" element to the text. By way of contrast, there is no better way to illustrate what I mean by a "proper textbook" based on the historical method than to summarize for readers the textbook that first pioneered this approach in the English language – Thomas Martin Lowry's *Historical Introduction to Chemistry*.


HISTORICAL
INTRODUCTION TO
CHEMISTRY

BY
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ST. MARTIN'S STREET, LONDON
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Figure 1. Title page of the author's personal copy of the second edition of Lowry's *Historical Introduction to Chemistry*.

Lowry's Pioneering Textbook

Lowry's textbook (figure 1) was first published in 1915, followed by a slightly expanded version in 1926, and yet a third expansion in 1936 (4). The book is divided into 20 chapters, each tracing the historical development of a key concept or subject up to whatever point in time that it had matured to an extent considered appropriate for a contemporary introductory chemistry course. Each chapter ends in a concise summary to aid

Figure 2. Thomas Martin Lowry (1874-1936)

the student in studying, and the chapters are further grouped into those dealing with descriptive chemistry (Part I of the book) and those dealing with theoretical concepts (Part II of the book). The book is richly illustrated with nearly 60 photos and etchings. All of these deal either with samples of various minerals and compounds or with historically significant chemical apparatus rather than with portraits of famous chemists. This is because, as Lowry emphasizes, the book is intended to deal with the subject matter of chemistry and not with biography *per se*. Nevertheless, at the end of the book Lowry does include a combination biographical/bibliographical index of significant chemists and publications mentioned in the various chapters.

Part I on descriptive chemistry includes 13 chapters on the history of the following subjects:

1. Raw Materials and Primitive Manufactures
2. The Acids [and Salts]
3. The Burning of Metals and the Discovery of Oxygen
4. Chalk, Lime, and the Alkalis
5. The Study of Gases
6. The Composition of Fixed Air, Carbon, Carbonic Acid and the Carbonates
7. The Burning of Inflammable Air and the Composition of Water
8. The Burning of Inflammable Gases, Liquids and Solids
9. Sulphur and Phosphorus
10. Nitre, Nitric Acid, and Nitrogen
11. Muriatic Acid and Chlorine
12. The Halogens
13. The Decomposition of the Alkalis

Part II on theoretical chemistry includes seven chapters on the history of the following subjects:

14. The Atomic Theory
15. The Molecular Theory
16. Atomic Weights of the Metals
17. Molecular Architecture
18. The Classification of the Elements
19. Balanced Actions [i.e. Equilibrium]
20. Dissociation [Equilibrium con't]

As already stated, the terminal date for each chapter is heavily dependent on the subject matter. Thus Chapter 2 on acids (bases and salts) terminates in the 18th century with Rouelle's generalization of these concepts, whereas Chapter 18 terminates around 1920 with the work of Moseley on atomic numbers and Aston on mass spectra and isotopes. Though admitting to having consulted standard histories of chemistry, such as those by Thomson and Kopp, Lowry states that most of the book was based on his personal study of the primary chemical literature. Not only does he include etchings of original apparatus in order to illustrate for the student how the research was done, he also frequently includes direct quotations from the original papers – a task made easier, as he admits, by the availability of the recently published *Alembic Club* reprint and translation series.

As indicated by this all too brief summary, all of this is a far cry from simply sprinkling a few decorative portraits of assorted famous chemists throughout a conventional chemistry textbook and illustrates what I consider to be a proper use of an historical approach to the teaching of introductory chemistry.

Who Was Thomas Martin Lowry?

Thomas Martin Lowry (figure 2) was born on 26 October 1874 in Low Moor, Bradford, the second son of the Reverend Edward P. Lowry, senior Wesleyan Chaplin and a staff officer at Aldershot, a major garrison town for the British army. Like his father, Thomas would remain a devout member of the Methodist Church his entire life, eventually serving on the boards of many of its associated organizations, and even occasionally functioning as a lay minister. Not only had his forebears been Methodists for several generations, in 1904 he would make the association complete by marrying

the daughter of a Methodist minister (5). As one biographical account would later summarize the situation, "It is against this background of Lowry the Methodist that Lowry the scientist must be seen" (6).

Lowry's secondary education was obtained at Kingswood School in Bath, a Methodist boarding school founded by John Wesley in 1748. In 1893 he entered the Central Technical College of the City and Guilds Institute in South Kensington and, upon graduation in 1896, became an assistant there to the iconoclastic organic chemist, Henry Armstrong, leading to a D.Sc degree granted by the University of London in 1899. While working with Armstrong, Lowry simultaneously served, from 1904 on, as a Lecturer in Chemistry at the Westminster Training College, which specialized in the education of teachers for Methodist schools. These associations ended in 1913 when he was appointed head of the chemical department at Guy's Hospital Medical School and as a Professor of Chemistry at the University of London. Finally, in 1920 he was appointed to the newly established chair of Physical Chemistry at Cambridge University, where he remained until his untimely death on 02 November 1936 at age 62.

Described as a shy and quiet man who loved dogs (figure 3), Lowry was nevertheless the recipient of many honors, including membership in the Royal Society, President of the Faraday Society, Vice-President of the Chemical Society, and several honorary degrees from various universities. He was also awarded a C.B.E. (7) and the Italian Order of St. Maurice and St. Lazarus for his services during World War I in connection with solving the problems of shell-filling using the explosive mixture known as Amatol.

During his years with Armstrong, Lowry developed an interest in dynamic isomerism, which is to say, the spontaneous interconversion of two isomers in solution leading to an equilibrium mixture of the two. This he first observed with the optical isomers of camphor derivatives – a phenomenon which he dubbed "mutarotation" since the path to equilibrium was correlated with a continuous variation in the optical rotation of the solution. This led, in turn, to a life-long interest in the phenomenon of optical isomerism and to the eventual publication of two definitive monographs on the subject (8, 9).

After his move to Cambridge, Lowry became increasingly involved in the second phase of the development of the modern electronic theory of organic chemistry based on the application of G. N. Lewis's shared electron-pair bond (10). He is generally considered to be the fourth member of the quartet of British chemists most responsible for this development. Known as the so-called "English school" of organic chemistry, they would include, in addition to Lowry, Arthur Lapworth, Robert Robinson, and Christopher Ingold (11). Lowry hoped to summarize his vision of this new approach to organic chemistry in a monograph entitled *Physical Aspects of Organic Chemistry* and, though he wrote much of the manuscript, increasing ill health soon caused him to seek the assistance of his former student, William Waters, and to eventually drop out of the project altogether. The book was finally published in 1935, one year before Lowry's death, under Waters' name alone (12).

One byproduct of Lowry's interest in the newer electronic theory of organic chemistry involved the interpretation of a type of dynamic isomerism that he called "prototropy" in which the two isomers in equilibrium were interconverted by the migration of a proton from one position within the molecule to another. Since the sites of proton attachment corresponded to a variety of functional groups, this caused him to question the Arrhenius identification of basicity with the OH^- anion alone and to formulate, independently of the Danish chemist, Johannes Brønsted, a new set of acid-base definitions in which acids were defined as proton donors and bases as proton acceptors (13). Now known as the Brønsted-Lowry proton definitions, this is probably the only contribution of Lowry still known to most present-day chemists, though one that Lowry

Figure 3. Lowry in his garden with his favorite dog "Taffy."

himself considered to be of trivial importance.

In addition to his *Historical Introduction to Chemistry*, Lowry's other "teaching books" included his massive (1101 pages) text, *Inorganic Chemistry,* first published in 1922 and revised and enlarged in 1931 (14). This was followed by several collaborative works, including an introduction to organic chemistry, coauthored with Percy C. Austin and first published in 1925 (15), and an introductory combination laboratory manual and textbook of physical chemistry, coauthored with Samuel Sugden and first published in 1929 (16). A final textbook, coauthored with A. C. Cavell, was published the year of Lowry's death under the title of *Intermediate Chemistry* (17). This was essentially a condensation of Lowry's previous textbooks on inorganic, organic and physical chemistry, with added sections on qualitative and quantitative analysis and 190 simple laboratory experiments.

There is one final fact concerning Lowry's life, or rather his death, that is missing from the official biographical accounts, but which was revealed in the autobiography of the German physicist, Max Born. Of Jewish descent, Born and his wife Hedwig were forced to flee Germany in 1933 and to initially seek refuge at Cambridge University, where they first met Lowry (18):

The professor of physical chemistry, Lowry, came to see me because he was interested in my work on the optical activity of asymmetrical molecules and crystal lattices. He became very much attached to us, took us in his car for little excursions and showed us the Gog and Magog hills just outside Cambridge where there was a tiny "wood," so small that one could look right through it – it did not mitigate our homesickness for German forests but even increased it. He was a most friendly and kind man, a little philistine and with narrow interests. We were deeply shocked when we later learned that he had committed suicide. It is still a riddle to me what dark experience may have driven this quiet, even-tempered, kind man to such a desperate step – probably the knowledge that he was suffering from an incurable disease (cancer).

Given Lowry's devout religious views and the fact that he would have left behind a wife and three grown children, it must necessarily have been a "dark experience" indeed that would have forced him to take such a desperate step. However, it appears that Born's report of Lowry's suicide is based on a misunderstanding. At the author's request for further information on the subject, British historian of chemistry, Peter Morris, kindly scanned British newspaper files for the 1930s and also examined Lowry's death certificate, but could find no evidence of a suicide, the latter indicating instead that he died from a heart attack due to hardening of the arteries. What he did discover, however, was that in 1939, or three years after Lowry's death, a young dentist with the identical name of Thomas Martin Lowry did commit suicide. By then the Borns were living in Edinburgh and Dr. Morris is of the opinion that they indirectly heard of this latter suicide and simply assumed that it was the Lowry they had briefly known several years earlier in Cambridge (19). All of this leaves open the question of why Lowry progressively disengaged from the book project with William Waters, though stress may have played a role, since Lowry was a driven man who, in addition to the many books listed above, also authored or coauthored more than 300 research papers – an astounding number for a chemist of this period, though not uncommon today among ambitious academic chemists with large research groups.

The Target Audience

The standard biographical account of Lowry's life makes the claim that a leading characteristic of his career, as both a teacher and a researcher, was (6):

... the belief, to which he adhered faithfully throughout his life, that a true knowledge of a science can only be acquired when its historical development is understood.

Yet there is little evidence that he displayed a serious interest in history of chemistry either prior to or subsequent to writing his *Historical Introduction to Chemistry*. While it is true that he used abridged versions of several of the chapters from this book in the introductory section of his later textbook, *Inorganic Chemistry*, the vast majority of that book shows no vestige of an historical approach, and the same is equally true of his other introductory textbooks as well. His advanced monograph on *Optical Rotary Power*, on the other hand, carefully documents the background history of the subject, but this coverage is of the type that is normally expected when writing a thorough review of a research topic of contemporary interest.

Nor does the preface to the *Historical Introduction to Chemistry* provide an unambiguous account of when, where and why Lowry developed this particular approach to teaching introductory chemistry (4):

... the book may be commended to those who are responsible for the training of teachers, as well as students who intend to become teachers themselves. The historical method has also been found to provide a complete solution to the difficult problem of teaching mixed classes of students, some absolute beginners and

others with a considerable knowledge of elementary textbooks of chemistry. The problem is insistent in training colleges and medical schools, and is probably but little less urgent in other departments of teaching. The material included in this volume has been proved, by several years of actual practice, to provide a means of interesting and instructing both types of students.

Though the book was first published during Lowry's tenure at Guy's Hospital Medical School, we can infer from these comments that its contents were largely the product of his earlier teaching experiences at the Westminster Training College for Methodist school teachers and may have been a reaction to his earlier negative experiences, while Armstrong's assistant at the Central Technical College, with those "noisy engineers to whom I tried to teach physical chemistry at South Kensington" (6). The preface also seems to imply that Lowry continued to use this approach when teaching chemistry to the medical students at Guy's, though I find this hard to believe, since medical students, like engineering students, are well known for their extreme intolerance of anything that does not speak directly to what they perceive as their immediate vocational needs, and neither group would be likely to tolerate long historical digressions on subjects that they would most likely consider to be irrelevant to their future professions.

Critical Evaluation

There are two pertinent criticisms that may be made with respect to Lowry's historical approach. The first is that it was purely qualitative in nature and did not require students to work numerical problems. However, relative to this criticism, one must remember that when Lowry's text was first published most introductory chemistry courses dealt with descriptive, rather than physical, chemistry and were also mostly qualitative in their coverage. In addition, it can be argued that such an approach was probably more appropriate for the kind of students (secondary teachers) for whom the course was intended than is our more modern mathematical version.

The second, and perhaps more germane, criticism is that the historical approach was very time consuming. It takes Lowry more than 538 pages of text to provide an introductory historical account of elementary chemical concepts as they existed by roughly 1880 and, even then, certain key developments are either missing (e.g., the ionic theory of dissociation) or are barely mentioned (e.g. less than a sentence devoted to the tetrahedral carbon atom).

Though this limited coverage may not be a serious problem in chemistry courses directed at nonscience majors, in the case of chemistry courses designed for the training of future scientists it becomes a serious problem indeed, as Lowry's younger contemporary, the British radiochemist, John Cranston (figure 4), first pointed out in 1947 (20):

Figure 4. John Arnold Cranston
(1891 - 1972)

The question arises as to whether the study of the historical development of chemical laws, as valuable as it is, has not been purchased at too great a price. All teachers realize that the science of chemistry has grown so rapidly that many developments of the greatest practical importance can hardly be mentioned by the time that the student obtains a university degree in the subject. Some matter must be cut out and short cuts must be taken if this defect is to be remedied.

Cranston's proposed solution was ruthless in the extreme and the direct antithesis of Lowry's historical approach (20):

It appears to the author that no more promising step in this direction could be taken then by ruthlessly cutting out the historical approach to the subject. The study then becomes a rational one. The physicist's atom is taken as the starting point and a reasonably detailed picture of its structure is drawn. The fundamental laws of chemistry, the concepts of valency, the reactivities of the various elements, and the ionic hypothesis, then

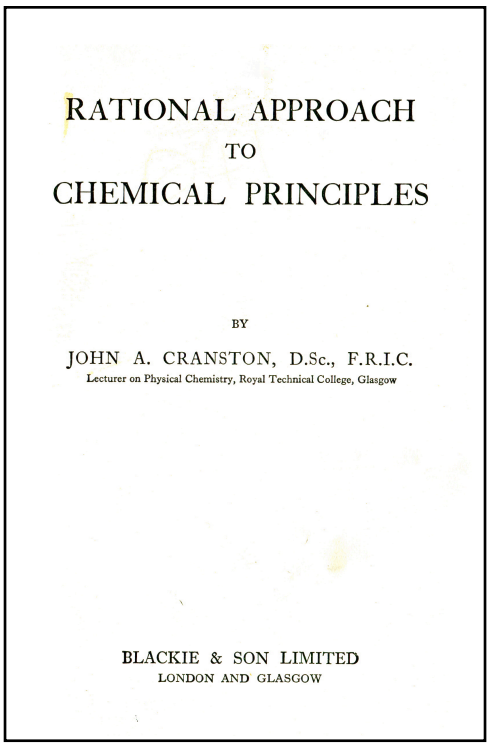
RATIONAL APPROACH
TO
CHEMICAL PRINCIPLES

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Figure 5. Title page to Cranston's 1947 text, *Rational Approach to Chemical Principles*.

tumble out of the picture in a perfectly rational way. Armed with these concepts, plus the purely mechanical one embodied in the law of mass action, the student is then very well equipped to tackle the factual aspect of chemistry. The whole study has become integrated.

The result was a concise, 200-page, small 5.5" x 7" format, introductory account of physical chemistry for the beginner, first published in 1947 under the provocative title (figure 5) of a *Rational Approach to Chemical Principles* (20, 21). At less than 40% the length of Lowry's textbook, it provided the student with an up-to-date account, unencumbered by either history or an overemphasis on numerical problem solving, of introductory physical chemistry as it existed at the time of the book's writing. Indeed, so clear is Cranston's account that, had I been aware of its existence when I was still actively teaching, I would have been tempted to use a slightly updated version in my own classes.

Whether the reader sides with Lowry or with Cranston on this issue, there is little doubt that Lowry deserves to be credited with founding the historical approach to the teaching of introductory chemistry and that every modern advocate of this approach should take the time to read his pioneering textbook, be it for inspiration, guidance or, perhaps, as a possible cautionary tale (21).

References and Notes

1. A possible exception to this date is J. Appleton's 1888 book, *Beginners' Handbook of Chemistry*, Chautauqua Press: New York, NY, which is resplendent with woodcuts of famous chemists and historical apparatus. However, this was not intended to be a true textbook for classroom use but rather a popularization intended for the general public.

2. Typical American examples include textbooks using portraits of such Americans as John Winthrop Jr., Ira Remsen, Theodore Richards, B. Smith Hopkins, Charles Martin Hall, Harold Urey, G. N. Lewis, and Irving Langmuir. Only some of these, such as Lewis and Langmur, are now considered to be historically significant.

3. Typical Russian examples from the Soviet period include textbooks using portraits of such Russians as N. V. Lomonosov, D. I, Mendeleev, N. S. Kurnakov, N. A. Menshutkin, Y. I. Mikhailenko, L. V. Pisarzhevsky and L. A. Chugaev. Once again this is a mixture of significant and purely secondary figures.

4. T. M. Lowry, *Historical Introduction to Chemistry*, Macmillan: London, 1915, 2nd ed., 1926, 3rd ed., 1936.

5. W. J. Pope, "Thomas Martin Lowry, 1874-1936," *Obit. Notices Fellows Roy. Soc.*, **1938**, *2(6)*, 287-293.

6. C. B. Allsop, W. A. Waters, "Thomas Martin Lowry," in A. Findlay, W. H. Mills, Eds., *British Chemists*, Chemical Society: London, 1947, pp. 402-418.

7. CBE is the abbreviation for Commander of the Most Excellent Order of the British Empire.

8. T. M. Lowry, *The Optical Rotation of Liquids: Its Variation with Wavelength, Temperature, Solvent, and Concentration*, U.S. Bureau of Standards, Miscellaneous Publications No. 118, Washington, DC, 1932.

9. T. M. Lowry, *Optical Rotary Power*, Longmans, Green: London, 1935. Reprinted by Dover Books in 1964.

10. The first phase, known as the American school of organic chemistry, was based on the use of the ionic model to explain organic reactions.

11. For a recent summary of Lowry's contributions to the electronic theory of organic chemistry, see M. J. Saltzman, "Thomas Martin Lowry and the Mixed Multiple Bond," *Bull. Hist. Chem.*, **1997**, *20*, 10-17.

12. W. A. Waters, *Physical Aspects of Organic Chemistry*, Routledge: London, 1935.

13. T. M. Lowry, "The Uniqueness of Hydrogen," *Chem. Ind. (London)*, **1923**, *42*, 43-47.

14. T. M. Lowry, *Inorganic Chemistry*, Macmillan: London, 1922, 2nd ed., 1931.

15. T. M. Lowry, P. C. Austin, *Organic Chemistry*, Macmillan: London, 1925, 2nd ed., 1931.

16. T. M. Lowry, S. Sugden, *Class Book of Physical Chemistry,* Macmillan: London, 1929. Frequently reprinted throughout the 1930s and 1940s.

17. T. M. Lowry, A. C. Cavell, *Intermediate Chemistry*, Macmillan: London, 1936, 2nd ed. 1939.

18. M. Born, *My Life: Recollections of a Nobel Laureate*, Scribner: New York, NY, 1975, p. 268.

19. e-mail correspondence 3/9/16.

20. J. A. Cranston, *Rational Approach to Chemical Principles*, Blackie: London, 1947, p. vi.

21. I might add in Cranston's defense that he was no stranger to writing history of chemistry himself and earlier in his career he coauthored a classic monograph on the history of chemical symbolism. See R. M. Caven, J. A. Cranston, *Symbols and Formulae in Chemistry: An Historical Study*, Blackie: London, 1928.

22. Yet a third possible criticism of the historical approach is that it requires students to read and evaluate large amounts of printed matter, which, for a generation used to the short info bits typical of i-phones, text messaging and computer websites, is becoming an ever greater imposition.

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