mained an important consideration. The flow-type calomel electrode could be replaced by one designed to give an almost negligible flow of potassium chloride solution. One of the most successful designs, described in 1947, made use of a controlled-crack junction tube (19). Pyrex glass was used for the body of the tube. A hole 5 to 10 mm in diameter was blown in the bottom and the hole was closed by sealing in a plug of glass having a high coefficient of expansion. After proper annealing, a permanent crack of controlled dimensions was obtained. A typical leak rate was 0.006 mL/hr.

Because of improvements in instrumentation, the high resistance of the glass electrode ceased to be a handicap, and it became the pH electrode of choice. Once this had occurred, highly-specialized glasses that provided a stable, much improved performance were discovered and exploited (20-22).

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OLD CHEMISTRIES

James Tytler's "A System of Chemistry"

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In the year 1791, the United States was slowly becoming a nation. George Washington was in the third year of his presidency. Vermont became the 14th state. The Bill of Rights amendments to the Constitution went into effect. And Philadelphia publisher Thomas Dobson marketed *A System of Chemistry* (1). This volume was the second full-size chemistry book published in America (2) and the first American imprint to introduce the new chemistry of Lavoisier and his French colleagues (3).

A year earlier, Dobson had begun the ambitious task of publishing an American edition of the 18-volume *Encyclopaedia Britannica*. He was pirating the third Edinburgh edition of *Britannica*, which was issued in 300 parts from 1788 to 1797. As each part reached America, Dobson would have a few of the articles edited by Americans and issue half-volume sections every ten weeks. The American title, *Encyclopaedia; or Dictionary of Arts, Sciences and Miscellaneous Literature*, merely omitted the word "Britannica" from that of the Edinburgh edition. Title pages bear the date 1798 because front

pages were not printed until all 36 half-volumes were finished.

During 1791 Dobson was working on volume IV, which contained a 238- page article on chemistry (4). Using the same type prepared for the *Encyclopaedia*, he also published it as a separate monograph under the title, *A System of Chemistry*. Nicely bound in full calf, the volume used superior quality paper manufactured in Pennsylvania and special type was cast for the work by Baine and Company of Philadelphia (5). With small print on 8 x 10 inch pages, it was the equivalent of 400 to 500 pages of typical size and type. It was an impressive, comprehensive treatise on chemistry, the first such published in America. Dobson would later pirate another treatise on chemistry from the *Britannica Supplement* of 1800. Table 1 summarizes the relationship of early chemistry to the *Encyclopaedia Britannica* (6).

Lavoisier's new nomenclature was mentioned in an appendix, which contained "discoveries as have appeared since the compilation of the article". It gave quotations from Lavoisier's explanation of the new system and inserted a folded chart contrasting the new names with the ancient names. This chart had been copied into the Edinburgh edition from the 1790 London edition of Fourcroy's *Elements of Natural History and Chemistry* (7). A personal comment from the *Britannica* author indicated that he was not yet converted to the new system: "Whatever may be the defects of the old one [nomenclature], we are ready to be involved in much greater difficulties by the introduction of a new one." Although admitting that the new system "has attracted no small degree of attention", he worried that future innovations would result in "endless vocabulary" (8).

Although no author is listed in *System of Chemistry*, it was written by James Tytler (1747-1805). An eccentric character, Tytler was at various times a chemist, physician, printer and publisher, literary hack, balloon aeronaut and political gadfly. He was commonly called "Balloon Tytler" from being the first person in Great Britain to fly in a hot air balloon. The poet Robert Burns described Tytler as (9):

... an obscure, tippling, though extraordinary body of the name of Tytler, commonly known under the name of Balloon Tytler, from his having projected a balloon; a mortal who, though he drudges about Edinburgh as a common printer, with leaky shoes, a sky-lighted hat, and knee-buckles as unlike as George-by-the-grace-of-God and Solomon-the-son-of-David, yet that same unknown mortal is author and compiler of three-fourths of Elliot's pompous *Encyclopaedia Britannica*, which he composed at half a guinea a week.

The preface to the Edinburgh third edition of *Britannica* stated (10):

Aerology, aerostation, chemistry, electricity, gunnery, hydrostatics, mechanics, meteorology with most separate articles in the various branches of natural history, we have reason to believe were compiled by Mr. James Tytler, chemist, a man who though his conduct has been marked by imprudence, possesses no common share of science and genius.

James Tytler (22)

The uncertainty of the editor George Glaig's statement is due to his being hired in 1793, after the work was well in progress. By that time, the original editor, Macfarquhar, had died and Tytler had left the country.

The preface of the *Britannica* also contained a cryptic acknowledgment to Joseph Black (11):

There is, however, no man to whom the proprietors of the *Encyclopaedia Britannica* feel themselves under greater obligation than to Dr. Black for the very handsome offer he made to the person who was at first entrusted with the chemical department of the work.

Joseph Black (1728-1799), professor of chemistry at the University of Edinburgh from 1766 to 1796, was the foremost British chemist of the time. It is not known what contribution Black made to Tytler's chemistry treatise. Perhaps he reviewed Tytler's work or perhaps he allowed Tytler to use his library. Although Black's *Lectures on Chemistry*, edited by John Robison, were not published until 1803, many student manuscript copies were in circulation at the time Tytler wrote his article. A comparison of Tytler's work with Black's *Lectures*, however, reveals no particular similarity. Tytler does not refer to Black any differently than other authorities. Indeed, Tytler mentions Crawford's work on heat more than that of Black.

One is impressed with the thoroughness of Tytler's *System of Chemistry*. It was a masterful composite of the state of chemistry in 1791. It reads as though Tytler had made an exhaustive search of the existing literature. He used current research from the *Philosophical Transactions* and the *Chemical Annals*, as well as from various "Berlin Memoirs", and "French Memoirs." Almost every paragraph named a scientist and gave a concise summary of his concept, experiment or contribution. Specific references were rarely given, but literally hundreds of authorities from many countries were identified with such phrases as "Mr. ___ has observed", "According to Mr. ___", "Dr. ___ is of the opinion", etc.

Few quotations were present; Tytler preferred to summarize the work of others. He was remarkably adept at extracting the essence of a large, complicated topic. He would often give the explanations of more than one person for the same concept. Although phlogistonist views were used, he recognized that Lavoisier had performed conflicting experiments.

Tytler does not appear to have used any single work as a basis for his treatise. The only sources he mentioned by name were: "The Chemical Dictionary" (probably Macquer's anonymous *Dictionnaire de Chymie*), Scheele's *Chemical Essays*, Lewis' *Commercium Philosophico-Technicum or Philosophical Commerce of the Arts*, "Kirwan's treatise on phlogiston", "Crawford's treatise on heat", "Shaw's edition of Boerhaave", and Wiegleb's *System of Chemistry*.

The book contained five sections: History (pages 5-8), Theory (pages 9-89), Practice (pages 89-230), Tables (pages 230a-246), and Index (pages 247-269). The contents were well outlined with headings and paragraph topics were given in margin notes. Three plates depicted chemical symbols, furnaces and glass laboratory vessels. In addition to the table of new nomenclature described above, there was a 15-page table of the classification of chemical substances. This table was an updated version of one that appeared in the 1771 first edition of *Encyclopaedia Britannica*. The extremely detailed index even included a few paragraphs of text that apparently were last -minute additions. Except for the page numbers, all contents were identical to the *Encyclopaedia* article on chemistry.

On three occasions Tytler inserted a personal viewpoint. One of these is quoted above in the discussion of Lavoisier's new nomenclature, but perhaps the others will give an insight into his personality (12). Thus on page 81:

> It seems surprising that this able chemist, who on other occasions had the improvement of the arts so much at heart, did not put some vessels of this kind of porcelain to other severe trials ... When a first rate chemist publishes any thing in an imperfect state, inferior ones are discouraged from attempting to finish what he has begun ...

and again on page 100:

> We cannot here help again regretting that chemists of superior

Table 1. Early Chemistry in the *Encyclopaedia Britannica* (6)

1st Edinburgh (3 v., 1771): Edited by William Smellie, who established the policy of comprehensive treatises on major subjects. The 114-page article on chemistry was essentially a copy of P. M. Macquer's *Elements of the Theory and Practice of Chemistry* (3rd, Edinburgh, 1768). A facsimile edition of the 1771 *Britannica* was published in 1968 (20).

2nd Edinburgh (10 v., 1777-1784): Edited and largely written by James Tytler. The 92-page article on chemistry was written by Tytler.

3rd Edinburgh (18 v., 1788-1797): Edited by George Glaig. James Tytler contributed some major science articles, including the 269-page article on chemistry.

1st Philadelphia (18 v., 1790-1798): Edited by Thomas Dobson. A partly rewritten copy of the 3rd Edinburgh. Published every ten weeks in 36 half-volume parts bound in boards. Complete 18 volume sets dated 1798 were bound in calf. The article on chemistry (v. IV, pp. 376-637) was a reprint of the Edinburgh original. This was also separately issued as *A System of Chemistry...* (pp. 269 plus folded chart, Philadelphia, 1791).

Supplement to 3rd Edinburgh (2 v., 1800-1801): Thomas Thomson wrote the chemistry treatise, introducing chemical symbols for the first time. This article became the basis of Thomson's *System of Chemistry* (4 v., Edinburgh, 1802). The first volume was anonymously reprinted as *A New System of Chemistry Comprising the Latest Discoveries and Improvements of the Science* (364 pp., Philadelphia, 1800). Although not on the title page, this volume also contained articles on mineralogy, animal and vegetable substances and dyeing substances. The chemistry article (pp. 1-198) was edited with footnotes by American scientist, Thomas P. Smith (21). A second reprinting appeared as *A New System of Chemistry including Mineralogy and Vegetable, Animal and Dyeing Substances* ... by Thomas Thomson (364 pp., Philadelphia, 1803): Except for title page, this was identical to the previous item (21).

Supplement to 3rd Philadelphia (3 v., 1803): The article on chemistry (v. I, pp. 257-453) was the same as that in the two previous items.

Supplement to 5th Edinburgh (6 v., 1816-1824): William Brande wrote one of the three keynote articles, "Dissertation Third: Exhibiting a General View of the Progress of Chemical Philosophy from the Early Ages to the end of the Eighteenth Century." This material became the preface to Brande's *Manual of Chemistry* (London, 1819), but was not included in the 1821 American edition edited by William J. Macneven. It was also reprinted as *Dissertation Third: Exhibiting a General View of the Progress of Chemical Philosophy from the Early Ages to the End of the Eighteenth Century*, By William Thomas Brande (120 pp., Boston, Wells and Lilly, 1818).

abilities should sometimes leave very important discoveries only half finished, so that chemists of inferior rank know not what to make of them.

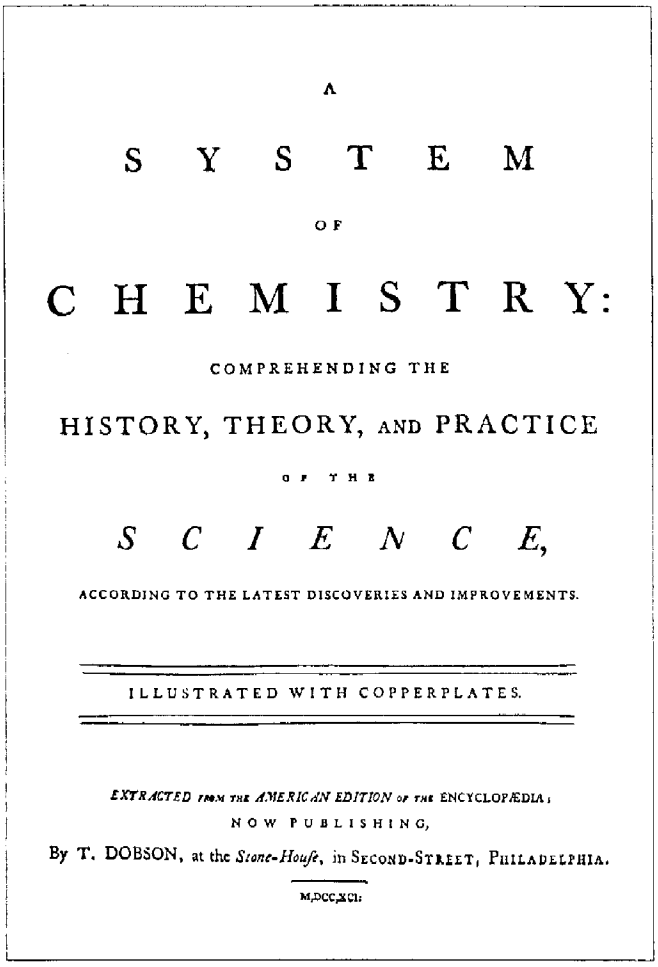
James Tytler was born in 1745 in rural Scotland, where his father was a minister in the parish of Fearn (13). At an early age he was apprenticed to a local surgeon. About 1764 he enrolled in medical classes at the University of Edinburgh, where he studied chemistry under William Cullen.

During the following summer, Tytler served as a surgeon aboard the whaling ship *Royal Bounty* in the Greenland seas. Two months after his return to Edinburgh, at age 20, he was married to Elizabeth Rattray. This early marriage undoubtedly damaged a promising career. He did not return to medical classes and began a permanent struggle against poverty. Recognizing that he was inadequately prepared to practice medicine, he opened an apothecary shop. In 1766 this business failed and he fled to Northern England to escape debtors prison. He continued to make a precarious living as a chemist, preparing medicines for established apothecaries.

Returning to Edinburgh in 1772, he gradually turned to writing as a means of support. He began publishing a weekly magazine, but it failed after several months. He constructed his own printing press and published several religious works. Establishing a reputation as a "booksellers hack," he supplied translations, compilations and ghost articles for many publishers. He was uncommonly adept at abridging large works, which he often composed directly into type without writing a manuscript. His versatility, however, was not matched by business success. He was paid trifling sums. He drank heavily, lived in poverty, and provided miserably for his wife and five children. About 1775, his wife deserted him and took the children to live with her family. A second wife died in childbirth in 1782 and a third wife survived him, but poverty was their constant lot.

In 1775 debts caused Tytler to again flee prosecution. This time he took refuge, under the right of sanctuary, in the Abbey of Holyrood, registering as "James Tytler, chymist in Leith" (14). By 1776 he was back in Edinburgh and accepted the offer of Bell and Macfarquhar to edit the second edition of the *Encyclopaedia Britannica* for 17 shillings a week.

Tytler labored on the *Britannica* from 1776 to 1784. It was published in 101 parts and then bound as ten volumes. Some of the articles were carried over from the first edition (published in three volumes in 1771), but Tytler wrote an astonishing three fourths of the 9000 pages, including the 92-page article on chemistry. In spite of this demanding task, he pursued other literary enterprises. Another weekly magazine lasted about six months. He began an abridgement of a 20-volume history of the world, composing at the type case with the open volumes before him. Only one volume of this abridgement, *The General History of All Nations, Ancient and Modern*, covering from antiquity down to Alexander the Great, was published. He also published two English poetry translations of Virgil's works.



A

SYSTEM

OF

CHEMISTRY:

COMPREHENDING THE

HISTORY, THEORY, AND PRACTICE

OF THE

SCIENCE,

ACCORDING TO THE LATEST DISCOVERIES AND IMPROVEMENTS.

ILLUSTRATED WITH COPPERPLATES.

EXTRACTED from the AMERICAN EDITION of the ENCYCLOPÆDIA;
NOW PUBLISHING,
By T. DOBSON, at the *Stone-House*, in SECOND-STREET, PHILADELPHIA.

M,DCC,XCI.

While writing articles on "Flying" and "Air Balloons" for the *Encyclopaedia*, Tytler became fascinated with the possibility of manned flight. The Montgolfier brothers had successfully ascended in a hot air balloon in France only the previous year. On 19 June 1784, the following advertisement appeared in the *Edinburgh Evening Courant* (15):

> On Monday next, the 21st current, will be exhibited at Comely Garden by James Tytler, chemist, a fire balloon, of 13 feet in circumference, as a model of the Grand Edinburgh Fire Balloon, with which he intends to attempt the navigation of the atmosphere. As this exhibition is intended to give the public a demonstration of the principles upon which the Great Balloon will ascend ...

In an effort to gain subscriptions to finance his work, Tytler displayed the finished "Grand Edinburgh Fire Balloon" on 17 July 1784. It was 40 feet high and 30 feet in diameter, with a basket hung below that carried the aeronaut and a stove. Because the stove weighed so much, Tytler removed it when

the balloon was ready to ascend. After several failures and postponements, on 27 August 1784 Tytler became the first person in Great Britain to "navigate the air." Although the flight was only about half a mile and reached only 350 feet, Tytler was hailed as a courageous pioneer. He designed a larger stove and made other unsuccessful attempts. In a final trial, this time keeping the stove aboard, the balloon hit a tree and the stove exploded. The balloon was heavily damaged and Tytler barely escaped injury. Public excitement waned and balloon trials ceased, but Tytler continued to be known as "Balloon Tytler." Unable to profit from admissions to his balloon experiments, Tytler again found himself unable to meet his debts. For a second time he sought refuge in the debtors sanctuary at Holyrood, this time registering as "James Tytler, chemist and baloon [sic] maker in Edinburgh" (16).

By 1786, Tytler was back in Edinburgh working on the third edition of the *Encyclopaedia Britannica*. He was not editor of this edition, but contributed some scientific articles, including the 269-page treatise on chemistry. Interestingly, his articles on aerology and aerostation did not include any mention of his own efforts at balloon flight.

At the same time he was working on the *Britannica*, Tytler wrote comprehensive books on geography, travels and the history of Edinburgh. He published several songs and verses that came to the attention of the noted Scottish poet, Robert Burns. Burns' description of Tytler is quoted above. When Tytler wrote a pamphlet in defense of Mary, Queen of Scots, Burns sent his picture and "A poetical address to Mr. James Tytler," one stanza of which read (17):

I send you a trifle, a head of a bard,
A trifle scarcely worthy your care;
But accept it, good sir, as a mark of regard,
Sincere as a saint's dying prayer.

In 1788 Tytler's first wife, who had never been legally divorced, sued for divorce and damages. A summons was issued for "James Tytler, sometimes druggist in Leath, now chymist at or near Edinburgh" (18). Typically destitute, Tytler once again fled prosecution. The divorce was finally decreed while Tytler remained outside Scotland.

Upon his return to Edinburgh about 1791, Tytler became involved with a group advocating political reform. After he published several critical works, a warrant was issued for his arrest and he fled to Ireland. When he failed to appear before the court in 1793, he was banished from his native land. In 1795 he and his third family sailed for the United States.

Settling in Salem, Massachusetts, Tytler supported himself, as previously, by preparing medicines for druggists and by writing. He compiled an exhaustive *Treatise on the Plague and Yellow Fever* (1799). In 1801 he was hired by a Salem bookseller, at 121/2¢ an hour, to compile a "Universal Geography". He had nearly finished that task when, on the stormy night of 8 January 1805, he fell into flood waters and drowned.

Although writing may have been his means of livelihood, Tytler appeared to consider himself a chemist. No less than six extant official documents list his occupation in Scotland as chemist. In the 1780s he helped construct a manufactory for magnesia, but was dismissed as soon as he got it into production. He developed a bleach for linen which was stolen by clothing merchants. He often procrastinated his writing to carry out experiments, one of which was an effort to construct a perpetual motion machine. A surviving diary of a friend in America described him as "a well known chemist, forced to leave his native country on account of his political views" (19). After his death, his wife knew enough about his practice to advertise that she could prepare ether and other medicines for the medical profession.

It is impossible to tell what influence Tytler's *System of Chemistry* had on American science. It was not referenced in any of the American chemistry imprints from 1792 to 1800, when another *Britannica* article on chemistry was published. European works were available, but, as the only American systematic survey of chemistry, *System* must have been used by serious chemists. One wonders if Tytler ever saw a copy of this book. It was a remarkable contribution to his adopted country.

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8. Reference 1, p. 230.

9. Quoted in Kogan, reference 6, p. 21. Burns was referring to the second edition of *Britannica*. Elliot was a local bookseller.

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22. The engraving of Tytler is taken, with permission, from Kogan, reference 6, unpaginated illustrations at center of book. Another likeness is found in Fergusson, reference 13, p. 145.

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BOOK NOTES

From Caveman to Chemist, Hugh W. Salzberg, American Chemical Society, Washington, D.C., 1991. xix + 294 pp. (Typeset). $14.95 (Paper), $24.95 (Cloth).

There has never been a shortage of books dealing with the history of chemistry. In a 1974 bibliographic study, Jost Weyer listed no less than 71 general histories of chemistry written between 1561 and 1970 - a number which excludes specialized histories of subdisciplines, such as organic and analytical chemistry, and the equally voluminous literature dealing with the history of alchemy. Of these histories, 29, or roughly a third, are written in English or have appeared as English translations.

Upon examining the current edition of *Books in Print*, the chemist looking for a suitable text to use in a history of chemistry course, or just for personal study, will find that a surprisingly large number of these titles are still in print. Excluding, for obvious reasons, modern reproductions of the classics by Thomas Thomson, Adolphe Wurtz, Ernst von Meyer, and M. M. Pattison Muir (originally published in 1830, 1868, 1889, and 1907, respectively), this list includes 20th-century works by James Partington, Henry Leicester, Aaron Ihde, Isaac Asimov, and Cecil Schneer.

Of these, Ihde's 1964 volume, *The Development of Modern Chemistry*, is by far the most detailed. Now available in an inexpensive Dover paperback reprint, its 851 pages cover the period from the 18th century to around 1950. It also has the best selection of portraits and illustrations ever to appear in a general history of chemistry. Though its size and detail make it difficult to effectively use in a one-quarter course, it is the best single-volume reference still in print and belongs on the shelves of every serious collector of chemical literature.

A more manageable overview is the Dover reprint of Leicester's 1956 volume, *The Historical Background of Chemistry*. Unlike Ihde's more detailed work, it gives equal treatment to alchemy and pre-18th century chemistry, though at the expense of terminating its treatment of modern chemistry around 1920. At 260 pages, it is less than a third the length of Ihde's work, but purchases its brevity with a lack of detail and the absence of the fine selection of illustrations found in Ihde.

The most recent addition to Dover's list of quality paperbacks is their reproduction of Partington's classic 1937 volume, *A Short History of Chemistry*. Despite the fact that it is 20 years older than Leicester's work, it is quite similar in both its length (386 pages) and period of coverage (prehistory - 1920).

Asimov's 1965 book of identical title, *A Short History of Chemistry* (263 pages), was originally issued as an inexpensive paperback as part of Doubleday's Science Study Series. While it is certainly the most accessible account for the layman, it has no references and appears to have been based solely on secondary sources and encyclopedia articles. These problems, coupled with the fact that it is now only available as an expensive hardcover reproduction, largely preclude its use as a text in a serious history of chemistry course.

Perhaps the most iconoclastic history currently in print is Cecil Schneer's 1969 volume, *Mind and Matter* (305 pages). While primarily a history of chemistry, it attempts, as its title suggests, to inject sizable doses of the history of physics and materials science. Though at first glance this integration appears desirable, it actually produces a distortion of the history of chemistry itself. Thus, for example, the history of chemical thermodynamics, as developed by chemists, followed a very different path from the development of thermodynamics in physics, which is the version given by Schneer.

Despite this abundance of choices, the perceptive reader will have noticed that even the most recent of these volumes is now over 20 years old. As a result, historians have increasingly felt the need for a new history of chemistry that will not only cover the history of the last half century but also effectively integrate the new interpretations of the older periods developed