BULLETIN FOR THE HISTORY OF CHEMISTRY

Division of the History of Chemistry of the American Chemical Society

NUMBER 9 SPRING 1991

William Henry Perkin and the Rise and Fall of the British Dye Industry

BULLETIN FOR THE HISTORY OF CHEMISTRY, NO. 9, 1991

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The Cover...

This issue shows a retrospective caricature of the English chemist, William Henry Perkin (1838-1907), who discovered the aniline dye *mauve* in 1856. Perkin is featured in this issue in the article by Saltzman and Kessler, which suggests some parallels between the rise and decline of the British dye industry in the 19th century and the current problems of the American solid state electronics industry.

The deadline for the next issue (Fall 1991) is 30 November 1991. An Author's Guide appears on page 37 of the Fall 1990 issue.

CONTENTS

THE 1990 DEXTER ADDRESS

Records of Chemistry: Combustion or Conservation?

Colin A. Russell, The Open University

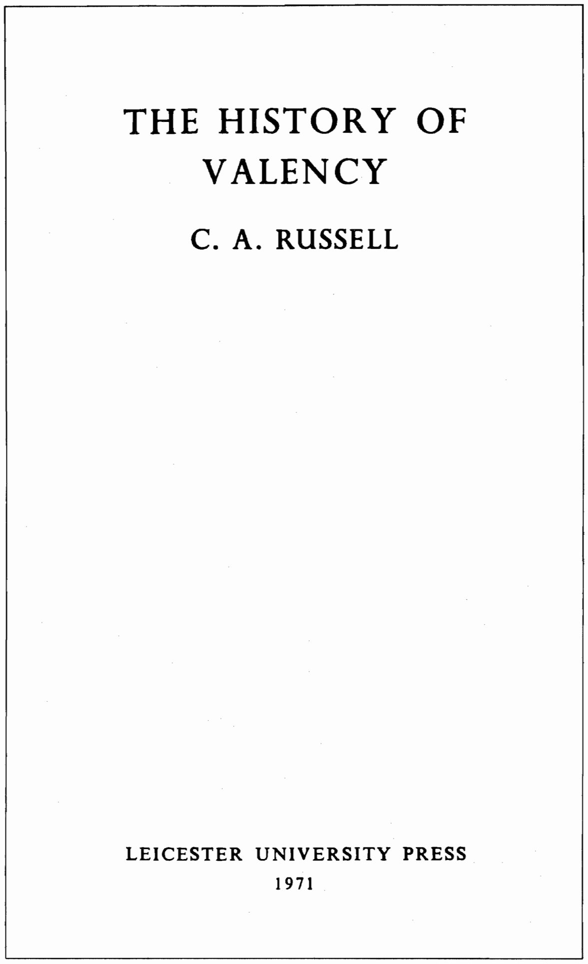
It gives me great pleasure to give this address to the ACS Division of the History of Chemistry, and to acknowledge with deep gratitude the generosity of both the ACS and the Dexter Corporation in granting me the 1990 Dexter Award.

One of my first tasks as a young chemist was to clear out an ancient storeroom. It was full of the most astonishing relics: glassware that was almost devitrified, chemicals never used in 30 years, stacks of old papers, and sodium cyanide in blocks shaped like coffin lids. All was disposed of swiftly and unceremoniously. Such ancient detritus was an offence to our sense of modernity, relics from an old technical college that were wholly unfit to grace what was to be an up-and-coming polytechnic. "Ancient and modern" might be a good title for an English hymnbook; it was utterly inappropriate as a motto for a modern chemist.

Our behaviour that day must have seemed quite typical. Chemists usually appear uninterested in objects from the past, be they literary records or old equipment. Over 150 years ago Thomas Thomson wrote disparagingly of the "rude and disgraceful beginnings" of chemical science (1). He was referring to alchemy. And today most chemists seem to share his embarrassment about their collective past and to manifest a selective amnesia.

Curiously, this ahistorical attitude is expressed at precisely the same time that, in other areas, there is a huge resurgence in historical interest. In the West there is a growing recognition of the value of history. It has been well said that a culture unaware of its history is like a man without a memory. "Forward, ever forward" may be a good watchword for lemmings; it is hardly so for civilisation, and I see no reason why it should be so for chemistry. Indeed, Thomson is a dangerous example to quote, for in fact he was concerned to promote the history of chemistry, as were many leading chemists until quite recently (2). The large scale rejection of the past amongst chemists - even a contempt for chemical history - is really a phenomenon of our own day.

But there are welcome signs of a maturing of attitudes and a return of interest in history of chemistry amongst the chemical profession. You, in the ACS, have set a shining example in having had for many years a full division devoted to history of chemistry. In Britain the RSC has a flourishing Historical Group (not yet a full Division) and many activities in which history is regularly and prominently to the fore. Now history cannot exist without records, any more than chemistry can exist without laboratories, so if history is becoming significant in chemistry, records themselves acquire a new importance. This is so for at least four specific reasons.



THE HISTORY OF
VALENCY

C. A. RUSSELL

LEICESTER UNIVERSITY PRESS
1971

* *Cultural Importance of Chemistry:* As a part of science, chemistry is a major aspect of human endeavour and a partial determinant of our culture. Its history is as relevant to a rounded understanding of our culture as is that of state, church or literature. Its methodology as a science midway between physics and biology is important as a means of understanding the nature of science. So it is not too surprising that our educators, in Britain at least, are laying new emphasis on scientific discoveries, past and present. For this purpose historical raw material is needed.

* *Contemporary Importance of the Chemical Industry:* Throughout Britain and America a vast variety of records are now piling up in libraries, record offices, etc., many of these being the archives of big business. One of the largest sectors of industrial enterprise is the chemical industry, but often it is also the most neglected. In the United Kingdom this is one of the major contributors to a positive balance of international trade, having many employees and much investment. On those grounds alone its archives are specially important.

* *Historical Importance of Chemistry:* Turning from the present to the past one encounters a further remarkable fact:

while the importance of chemistry is usually ignored in the teaching of 18th and 19th century history, this is most notably so at precisely the two points where its role was most critical. It is surely incontestable that in its gift to the early textile industry of soap, chlorine, and dyes, and in its provision of acids for pickling metals, chemistry made the industrial revolution possible. And, secondly, by its provision of gas-lighting, fertilisers and food, explosives (not necessarily military), medicine and much else, chemistry profoundly altered the quality of life for ordinary people, usually for the better. If one asks how the teaching of history could be so blinkered as to exclude such items, one cannot escape one obvious explanation: the sheer unavailability of sources.

* *Popular Image of Chemistry:* Under pressure from environmental lobbies the chemical community has developed a new sensitivity to its public image. At times it has been mercilessly caricatured and caricatures need exposing. Some of these are about the past, so reliable source material is urgently needed. This is an area in which systematic research has scarcely begun. Yet already evidence has appeared that "green" concerns are not new, that captains of industry were not all uncaring, that their work force was not always exploited. In many areas the history of science has shown the great danger of extrapolating from a few famous but isolated cases to sweeping generalisations. With chemistry it is imperative to explore its records to see just how typical were, for example, the contributions to atmospheric pollution by the Muspratts on Merseyside, or the combined industries of Widnes. Preliminary work suggests we may be in for surprises.

Chemical records are of many kinds. First, and most obviously, there are what are commonly called *archives.* These include manuscript books, papers and pamphlets, advertisements, letters, notebooks, ledgers, photographs, drawings, paintings, and other documents. Then there are also *artifacts*, such as apparatus, small objects, and of course industrial plants. In the present context we exclude printed books and shall focus particularly on written documents.

All historical documents offer challenges. Those relating to chemistry pose some particularly difficult and specific problems, of which the following are the most important:

* *Incomprehensibility:* Most professional archivists are not trained in science, and few languages can be more obscure to an ordinary keeper of records than that of chemistry. The effect can be imagined of presenting a specialist in medieval social history with a diagram of a catalytic converter, a planning application for an ammonia synthesis plant, or laboratory notebooks from the local university. Partly for this reason any documents of a chemical nature in a local repository are unlikely to be catalogued under "chemistry", so they are correspondingly hard to unearth.

* *Inaccessibility:* In private hands chemical archives present the difficulties commonly faced by scholars enquiring into the possibility of access: the inconvenience of intrusions into private homes, the possible embarrassment of owners if there are likely to be any skeletons in the cupboard, and so on. However, in corporate hands these problems are compounded into a daunting series of obstacles: "classified information", political embarrassment, modern image and so on.

* *Inflammability:* When my own research laboratory went up in flames one night, my research records were preserved only because the desk drawers were made watertight and fireproof by the firemen's hoses! They were fortunate survivors. The chemical industry is prone to much higher dangers than small laboratories or than other industrial installations (such as offices). For instance, in 1854 an acetic acid plant on the river Tyne (Hew Singers) was "utterly destroyed" by fire; next door was a warehouse with 1000 tons of sulphur and saltpetre. All adjacent buildings were swept away in the resulting inferno, and the flames leapt across the Tyne and destroyed buildings on both banks of the river. No one knows how many chemical records disappeared that day. Nor was this untypical of the vulnerability of chemical plants to fire. It is remarkable how many English chemical factories were named (or renamed) the "Phoenix Works"!

Not only documents but whole factories are irretrievably lost to posterity. Records of few other enterprises can be so vulnerable to fire. And it must be said that not all combustions have been accidental. In 1983 the Tharsis Chemical Company destroyed five tons of archives simply to make more space. And sometimes combustion is not the only means of destruction. The archives of the Fuller's Earth Union (c. 1890-1975) were damaged but not destroyed by a fire in the wooden shed in which they were housed, then dumped in a skip where they suffered several months of English weather. Now fragile beyond belief, and crumbling at almost a touch, they were microfilmed at the Surrey Record Office and their contents thus preserved.

It remains for me to mention briefly three projects concerned with chemical records undertaken recently by my own research group.

* *The Archives of Sir Edward Frankland:* In 1962 Pearce Williams wrote of "a trunk in an attic containing unpublished letters from Darwin, Huxley, Kolbe, Pasteur and a host of others ..." unfortunately not available to the scholar (3). I believe he may have been referring to the letters of the English chemist Sir Edward Frankland. The family who owns them have shown an understandable reluctance to accept intrusion by unknown scholars, but eventually were prepared to allow them to be microfilmed in their own home. Detailed examination revealed hundreds more letters than had previously been suspected, and subsequently three other collections were discovered, all in private hands. Nearly 4,000 documents have come to light. To identify, catalogue and (eventually) microfilm them became a major objective of the research group at the Open University (4).

Frankland was one of the leading chemists of the United

Kingdom in the 19th century, yet he is largely unknown today. The archives reveal the reason: a dark secret of illegitimacy precluded him from giving personal interviews and he remained an excessively shy, very private person. To this day no biography has appeared, and only now is the material for such a work available to scholars. Yet Frankland knew most leading scientists of his day, and was a member of the ACS and many other chemical bodies. Surviving correspondence includes 29 letters from Darwin.

Frankland was renowned for his work on water analysis, and his chemical analyses of drinking water fill many volumes of notebooks and occupy many letters. His work as an educator is represented by several sets of lecture notes, while correspondence with Kolbe and others throws much new light on his changing views on valence, structure and theoretical organic chemistry. Quite apart from technical material, the letters reveal his role in scientific politics and open up new ways of understanding the fine structure of Victorian science.

* *Archives of the British Chemical Industry:* In 1981 the Annual Conference of the British Records Association was concerned with scientific records. It became apparent that no systematic survey had ever been undertaken of those relating to the British chemical industry. The next year a Research Fellowship was set up by the Open University to deal with this problem and in due course Dr. Peter Morris was appointed. Suitable publicity in the press was followed by a protracted campaign of letter-writing to all known chemical firms and to all likely holders of archives (5). The years from 1983 to 1986 were devoted to fieldwork. In the following two years company histories were compiled and checked. In 1987 Dr. Morris rejoined us (as Royal Society/British Academy Research Fellow) and publication soon followed (6).

The responses from industry were diverse, though they were usually improved when our intention was understood of limiting our search to the years before 1914. In a few rare cases we were welcomed with open arms, usually by the few very large firms that already had their own archives in good order. More commonly we were given a cautious welcome, being given to understand that this was a special privilege not accorded to the general public. In some cases denial of access was absolute, and we could expect no exceptional treatment. And there were some companies who cheerfully denied having any archives, and (in a few cases) of ever having had any!

The results were as delightfully diverse as the responses had been. In all about 120 institutions were identified as archives holders (Record Offices, libraries, firms, etc.). Nearly 1000 constituent companies made some appearance in the 180 company entries that eventually constituted the bulk of our report. All manner of documents emerged, including laboratory books and inventories. Amongst the latter was a sales catalogue for an immense calico-printing works at Catterall in Lancashire, almost the only technical evidence of its scale; at the other extreme was the firm of H. Ogden (Sunderland), which had "a copperas bed, metal stills, coolers, acetic acid stills and condenser, a three-chaldron boat and one useful cart-horse!"

Sir Edward Frankland

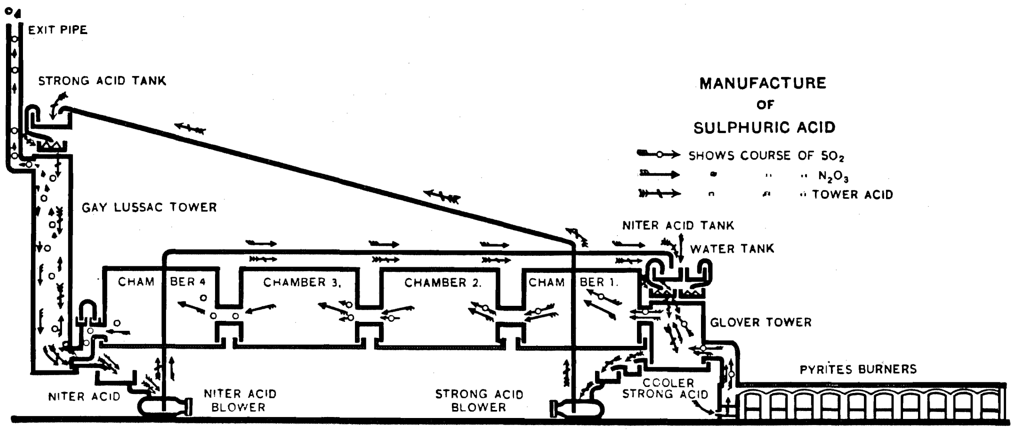
Then there were all kinds of plans and maps, legal documents (not merely about injunctions against pollution), advertisements, pamphlets, broadsheets, diaries and, of course, innumerable letters. We were particularly glad to discover a set of student lecture notes, taken by Peter Spence in 1854, from a course delivered by Edward Frankland at Owens College, Manchester.

* *Industrial Archaeology of the Chemical Industry:* At a time when industrial archaeology is attracting increasing attention, it may seem surprising that little has been done on the chemical industry. Our archives research revealed a number of surviving buildings in the United Kingdom, some still with their original function, but most now put to other uses. In some cases restoration is an urgent necessity. Although we have identified about 20 sites in Britain, much more must remain to be discovered and there is a pressing need for systematic cataloguing. If the research is broadened to include university and private laboratories, it would be the first comprehensive attempt to identify surviving "temples of chemistry", and even then in one country only. This is clearly a task for the future, perhaps through a new research fellowship.

We have, however, made some progress in locating old chemical plants. In connection with an undergraduate course (*Science and the Rise of Technology from 1800*) it was resolved to assemble existing archive film of chemical processes that were once of great importance. We had some success, for example, a revolving furnace from the Leblanc process and early shots of potash plants on Merseyside. But there was nothing like enough material for our purposes. So, in some desperation, we enquired whether any such processes had themselves survived into the 1970s. To our surprise, the result was positive. Since no one else had ever filmed most of them we decided to do the job ourselves (through the BBC) (7).

So there is now on record the last example of the puddling process for wrought iron (at Bolton). On the subject of explosives manufacture students were able to "visit" Waltham Abbey and the plant where gunpowder had been made for centuries, Nobel's original Scottish site at Ardeer, an early nitration plant for TNT, etc. in Galloway, and to witness an actual laboratory nitration of glycerol.

We were better pleased to find important relics of the coal-tar chemicals industry: some coke ovens from the early 19th century survive at Gateshead, as do a few men who once operated them; at Falkirk are some of the first tar-stills, and in Derbyshire an early nitration plant. And in a remote part of southwest Scotland was a coal carbonisation process still in use with horizontal hand-fired retorts of the 1840s design. To watch that process is still one of the most evocative ways I know of recapturing the essence of early 19th century chemical industry.



The lead chamber process for sulfuric acid as diagrammed in the 1909 edition of Thorp's *Outlines of Industrial Chemistry*.

But perhaps our greatest pleasure came from discovering and filming the world's last example of a process that was the foundation of Victorian Britain's economic prosperity: the lead chamber process for sulphuric acid. We discovered this survivor at Seaton Carew, on a windswept coast in northeast England. Never filmed before, the process yielded its secrets as the camera crew swarmed all over the plant: furnaces, Gay Lussac and Glover towers, the vast leaden chambers (including interior shots of one under repair); distant views conveyed something of its immense scale, as well as of the desolate landscape around; spoil heaps enabled us to trace changes in raw material and waste products; interviews with past and present staff gave the personal dimension; and in a ruined cottage were discovered invaluable plans of the whole site (8).

Within a few months of our filming, the Seaton Carew plant was closed down. The same fate befell the old coal carbonisation plant in a year or two. In each case we were just in time. How much more we might have accomplished had we started five years earlier will never be known. In whatever success we may have had, and still more in our failure, is a sombre illustration of both the richness of our chemical heritage and of the urgency with which problems of conservation and recording must be addressed.

References and Notes

Acknowledgments: This work has been carried out at the Open University, and very largely by a research team. I thank my colleagues in the Department of History of Science and Technology (especially Noel Coley, Peter Morris, Gerrylyn Roberts and Shirley Russell) and in the BBC (particularly David Jackson, Paul Kafno and Jim Stevenson). I gladly acknowledge the university's provision of a succession of research fellowships in the history of chemistry, and of numerous grants for travel and equipment.

1. T. Thomson, *The History of Chemistry*, London, 1830, p. 2.

2. C. A. Russell, "'Rude and Disgraceful Beginnings': A View of the History of Chemistry from the Nineteenth Century", *Brit. J. Hist. Sci.*, **1988**, *21*, 273-294 (Presidential Address to the British Society for the History of Science).

3. L. P. Williams, "The Physical Sciences in the First Half of the Nineteenth Century: Problems and Sources", *Hist. Sci.*, **1962**, *1*, 1-15.

4. C. A. Russell and S. P. Russell, "The Archives of Sir Edward Frankland: Resources, Problems and Methods", *Brit. J. Hist. Sci.*, **1990**, *23*, 175-185.

5. C. A. Russell, "Archives of the British Chemical Industry", *Indust. Chem. Bull.*, **1982**, *1*, 90.

6. P. J. Morris and C. A. Russell, *Archives of the British Chemical Industry: A Handlist*, British Society for the History of Science, 1988.

7. The TV films referred to below are as follows: From the course AST 281, *Science and the Rise of Technology from 1800*: No. 2: "Coal and the Nineteenth Century"; No. 3: "Sulphuric Acid and the Lead Chamber Process"; No. 7: "The Alkali Industry"; No.

8: "The Explosives Industry"; No. 9: "The Use of Ferrous Materials in Construction". From the course A281, *Technology and Change, 1750-1914:* No. 4: "The Alkali Industry"; No. 6: "Making Steel: An Industry Transformed". (This course also offers updated versions of Nos. 2, 3 and 9 from AST 281)

8. These plans are now in the Science Museum, London.

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THE RISE AND DECLINE OF THE BRITISH DYESTUFFS INDUSTRY:

An Object Lesson for American Industry

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Providence College

The aphorism that those who do not remember the past are condemned to live it again is an often quoted warning from the writings of George Santayana. This paper will attempt to illustrate this adage with two examples, one having historical and the other having contemporary significance. We will examine the rise and very rapid decline of the British synthetic dyestuffs industry as the historical example and the current dilemma of the American semiconductor industry as the contemporary example. Both industries were pioneers in the application of chemistry (organic in the former and solid state in the latter) to the development of entirely new technologies. Although our analogy may not be perfect, it is hoped that our study will elicit an awareness by the reader of the fact that history may indeed repeat itself.

The birth of the synthetic dye industry represents a classic example of serendipity in chemistry. During the 1856 Easter holidays William Henry Perkin (1838-1907), a student at the Royal College of Chemistry in London, working with its director August Wilhelm Hofmann (1818-1892), produced the first synthetic dyestuff - mauve or mauveine (19). Attempting to produce the drug quinine in his home laboratory by the oxidation of allyl toluidine with potassium dichromate, Perkin obtained a dirty reddish brown precipitate instead of the desired product. Persisting in his belief that quinine could be synthesized from aromatic amines, Perkin next oxidized commercial aniline, which was a mixture of aniline and toluidine. This resulted in a purple solution. It is a testimony to the keenness of Perkin's mind that he was able see the potential of this reaction mixture as a dyestuff - a potential which was confirmed when he sent some samples of silk that he had dyed with the mixture to Pullar & Sons, of Perth, Scotland, a silk and calico dyer. Thus, quite by chance, the synthetic dyestuffs industry was born and along with it the aromatic chemical industry.

William Henry Perkin at age 28

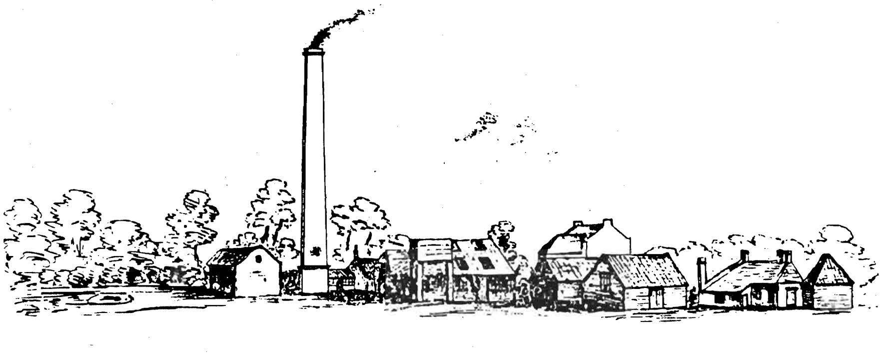
In retrospect the dye industry is the first example of a science-based industry. As Raphael Meldola stated in 1886 (1):

> The successive steps in this development ... [furnish] ... us with one of the most striking illustrations of the utilization of scientific discovery for industrial purposes, and the reaction of industry upon pure science.

What were some of the factors that were operative in Victorian Britain that led to the development of the dyestuffs industry? This era in British history was one of technological breakthroughs in many industries, such as machinery for the production of textiles and for mining. The acquisition of wealth by investing in the exploitation of natural resources was a route that was taken by many entrepreneurs of the day. The dyestuffs industry exploited a product known as coal tar which was produced in great abundance by the gas industry but which had little if any value. A large textile industry based upon imported cotton and wool was already in place which could readily absorb the products produced by the synthetic dye industry. Prior to Perkin's discovery, this industry used dyes which were almost exclusively obtained from natural materials, most of which had to be imported at great expense. In 1856 the figure of two million pounds sterling in real value has been given for these imports. Finally, educational institutions at this time were geared to the development of technologically based industries. As Travis has written (2):

> ... the environment (of practical men) provided problems to solve as well as the raw materials to be studied (by scientific men), and the educational institutions could only attract students if they offered adequate opportunities to acquire work-related skills, especially those required in the nearby area.

Perkin received a patent on 26 August 1856 for his new dye and with his father and brother established the firm of Perkin & Sons for the commercial production of the purple aniline dye. To convert a laboratory discovery into a commercial product was a major problem that had to be solved. The difficulties involved were many, such as securing sources of benzene from coal tar, developing a commercial-scale nitration procedure, as well as adapting to an industrial scale the reduction of nitrobenzene by iron filings first discovered by Béchamp in 1854 (3).



The Greenford Green Works in 1858

These problems were all solved and production of the dye which Perkin called Tyrian purple began at a plant built at Greenford Green west of London. In December of 1857 the first delivery of the new dye was made to the silk dyer Keith located in the Bethnal Green section of London. The dye was an instant success, especially in the fashionable circles of Parisian *haute couture* where it acquired the name mauve. In a period of less than 18 months, a laboratory discovery had been converted into a commercial product!

As shown in Table 1, in the next decade chemists in both Britain and France, by using various analogs of aniline and oxidation procedures, were able to produce a whole range of colors. Commercially the most significant of these was magenta. The reasons for this rapid advance were outlined by Perkin in 1868 (4):

> ... to introduce a new coal-tar colour after the Mauve was a comparatively simple matter. The difficulty in the manufacture of all the raw materials had been overcome, as well as the obstacles in the way of practical application of an aniline colour to the arts.

These discoveries also spawned a whole host of competitors for Perkin & Sons, among which the best known were Simpson, Maule & Nicholson in Britain and Renard Frères in France.

Table 1. Early evolution of aniline dyestuffs

Magenta	1859
Violet Imperial	1860
Bleu de Lyon	1861
Chrysaniline Yellow	1862
Aniline Black	1863
Methyl Violet	1866

The development of a commercial synthesis of the natural dye alizarin in 1869 marked the zenith of the British dye industry. Independently, Perkin in England and Heinrich Caro (1834-1910) in Germany devised a procedure to produce this natural dyestuff. Alazirin is an anthraquinone, the structure of which had been elucidated in 1868 by two students of Adolf Baeyer, Carl Graebe (1841-1927) and Carl Liebermann (1842-1914). Graebe and Liebermann took out a patent and assigned it to BASF, where Caro was able to make it into a viable commercial process. Caro had worked in the British dye industry from 1859-1866 during the heyday of the rapid development of aniline dyes and had returned to Germany to become technical director at BASF. At the same time, Perkin developed a four-step process for the synthesis of the dye starting from anthracene which involved chlorination, sulfonation, oxidation, and alkali fusion.

In 1874, as alizarin production was reaching its peak of 435 tons, Perkin & Sons was sold to the firm of Brooke, Simpson & Spiller, the largest dye manufacturer in Britain at that time. However, in this same year at BASF and Hoechst in Germany, alizarin production was already 1000 tons a year. Perkin realized that to compete with the newly-emerging German industry he would have to greatly expand his plant at Greenford Green. This was physically impossible so, instead, he and his brother sold out and Perkin withdrew from further active involvement in the dye industry, though not from chemistry. It has been argued by Travis that by 1870 Perkin was out of touch with what was happening in aromatic chemistry, and that he flourished in an environment which adapted technology to aromatic chemistry rather than the reverse, as exemplified in the approach of Caro (5). This may have also contributed to his removal from the business.

As Perkin was ending his active involvement in the dye industry, a new class of dyes known as the azo dyes was coming on stream. This class of dyes represents yet another example of where the original discoveries and production occurred in Britain but the advantage was soon lost to the emerging German industry. The diazotization reaction was discovered by the German chemist, Peter Griess (1829-1888), who spent the better part of his life working in England. Griess had been one of Hofmann's assistants (1858-1861) at the same Royal College of Chemistry where Perkin had received his training. In 1861 he took up employment as a brewery chemist and pursued his research in organic chemistry as a hobby. It was during this early period of Griess's work at the Allsop brewery in Burton-on-Trent that he discovered the diazotization process.

The first azo dye, called aniline yellow (*p*-aminoazobenzene), was formed by the coupling of the diazonium salt with aniline and its subsequent rearrangement. It was marketed in 1863 but did not prove very satisfactory in its application. Karl A. Martius (1838-1920), another German chemist working in Britain at Roberts, Dale & Co. in Manchester, produced the first successful commercial azo dye, Bismarck Brown, in 1866 as the product of the diazotization reaction of *m*-phenylenediamine instead of aniline. Another decade would pass before further azo dyes would appear. Caro in Germany and Otto Witt (1853-1915), another German working in Britain, produced simultaneously an orange azo dye called chrysodine. Chrysodine is the coupling product of *m*-phenylenediamine and benzenediazonium chloride. Thus we have seen that three of the most important classes of dyes were initially discovered and put into production in Britain in a period of about two decades. Yet by 1881 the distinguished British educator and chemist, Henry Enfield Roscoe (1833-1915) of the University of Manchester, would lament that (6):

> To Englishmen it is a somewhat mortifying reflection that whilst the raw materials from which all these coal-tar colours are made are produced in our country, the finished and valuable colours are nearly all manufactured in Germany.

By that year 50% of all dyestuffs were being made in Germany and by 1900 the figure would be 90%.

What were the factors that led to the decline of the British industry and to the development of such a dominant position by the German industry? They can be roughly classified as "external" - over which the British dye industry and chemical community had little control - and as "internal" - over which some degree of control existed.

The first of these, the external factors, were due largely to the lack of any kind of unified British industrial policy that would have fostered the dye industry and to a patent law that actually worked against it. The laissez-faire economic policy that pervaded Victorian Britain did little to protect domestic industry and all that was important was that the textile industry continue to obtain its dye requirements. The role of the state was not to help domestic industry compete with imports. In 1902, Ivan Levinstein (1845-1916), one of the most vocal of the dye manufacturers, complained that it was "difficult to get the House [of Commons] to consider any question of commercial importance" (7). Indeed, if the Germans could supply all that was required at a price less than domestic manufacturers, then all the better. This of course led to a rapid decline in the number of dye manufacturers after the 1880s and to a virtual end to technological development in the industry in Britain.

The dimensions of this decline can be seen in the number of British patents taken out between 1884 and 1900 by the six largest British and German firms. The number is 86 for British firms versus 948 for the Germans. By 1900 the six largest German firms employed 500 chemists whereas the British had a meager 35. Only with the advent of the First World War, when dyestuffs from Germany were no longer available, would the magnitude of the decline of the British dyestuffs industry clearly be seen. Then only reluctantly did the government intercede to try to rescue an industry that had basically collapsed under foreign competition.

The patent laws also played a role in the decline. There were no effective patent laws in Germany in the 1860s when the aniline dyes and alizarin were the major products. German firms were free to manufacture these dyes using information from the British patents. Even the new class of azo dyes were pirated; chrysodine for example, was copied by Martius at Agfa. Heinrich Caro best summarized this early period in the German industry, when he wrote (8):

> It was a joyless and profitless industry in those early years. It imitated the most valuable English and French inventions as described in the patent specifications ...

With the development of industrial research laboratories in Germany, the need for an effective patent law became evident. A patent law to protect the investment which various firms made in research was enacted for the whole German Empire and put into effect on 1 June 1877. This law was enacted only after input from a committee of the German Chemical Society as well as from the leading industrialists of the day. The law was rigorous, requiring that claims made for the product be valid, and thus, when a patent was granted, it became a valuable commodity. As R. D. Welham observed (9):

> ... there can be little doubt that the lack of a patent law, followed by the large profits to be made from the manufacture of magenta and alizarin, created the conditions for the rapid expansion of the German industry after its retarded start.

The patent laws in Britain were less strict and thus made it very easy for the Germans to patent large numbers of dyes. In addition, nothing required the patent holder to manufacture the product or, for that matter, to license its production in Britain to firms willing to meet the expenses of start-up and marketing. With the advent of the German industrial research laboratory and various types of new dyes, the patent laws led to a virtual monopoly by the Germans in the British market. Reform of the patent laws occurred in 1883 but was totally ineffective in terms of its working clause. The law was proposed without any input from the chemical industry and the clause requiring a patent holder to manufacture the product or license it was easily evaded. Even if a strict working clause had been included, it would have forced the Germans to set up plants in Britain where the raw materials were readily available. This would have done nothing for the domestic industry as a whole. A good analogy are the inroads made by Japanese manufacturers of automobiles, consumer electronics and machine tools in the United States. Although this is not the result of any patent law, it is still analogous in the sense that these foreign-owned firms manufacture in the U.S. to avoid loss of their market due to quotas and are now competing directly with domestic firms.

An effective patent law was finally passed in 1907 but it was essentially of little value to a dye industry which was already in terminal decline. The point can be made that even if compulsory licensing had occurred, it would have made little difference. German firms could have offered their products at prices much lower than the British licensee since the German industry was so much more modern and efficient by this time.

The most significant internal factor for the decline was the British educational system. Although there was probably no shortage of trained chemists in Britain throughout the period between 1856-1914, it was the type of training that was at the center of the problem. Institutions of higher education moved further and further away from a concern with practical research and became more and more involved in doing work which advanced the science of chemistry rather than the industry. Training of chemists tended to focus on the ability to perform research rather than on vocational training. The attitude taken by the dye industry toward this training was a major factor in its decline. British manufacturers were terribly short-sighted in terms of the value they placed on long-term research versus short-term profitability. In the early days of the industry, when Britain was in an almost monopolistic position, the profits that accrued were quite large. There was then a great reluctance to see that growing competition was going to end these easily-made profits and that profits must be plowed back in the form of research and development. The Germans, on the other hand, were quite willing to do this, just as the Japanese are today.

British manufacturers agitated not for better research training but for better technical education. They wished newly employed chemists to have a working knowledge of the dye industry so they would not have to pay salaries for what they considered an excessive period of time before these persons would become productive. A Royal Commission set up to study technical education reported in 1884 that (10):

> The Englishman is accustomed to seek for an immediate return and has yet to learn that an extended and systematic education up to and including original research is now a necessary preliminary to the fullest development of industry.

Another major fault of the English educational system was the way in which it trained its managers. A general classical education which completely neglected any training in the sciences was the norm. Many people who became involved in the more technical aspects of the business were woefully inadequate for the job. The Germans had a superb system of education, particularly on the secondary level, that included science and mathematics. This produced the type of person who could run the technical service departments and take charge of the routine control of processes to produce a consistently high-quality product. In general the Germans were better suited to realize the problems of the industry and were more responsive to the concerns of manufacturers than were the British.

In Britain the early retirement of Perkin at age 38 and Edward C. Nicholson (1827-1890) at age 41 deprived the industry of two manufacturers who had started their careers as chemists. Nicholson was also a student of Hofmann at the Royal College of Chemistry and had discovered magenta. Both realized the necessity for the reinvestment of profits in continuing research with the chance that it might ultimately pay off. With the loss of persons of this type the industry was run by those who were primarily businessmen. It was far different in the German industry, as many of the early dye pioneers, several of whom, like Caro, Martius, and Witt, had worked in Britain, eventually came to hold managerial positions with the large German companies set up in the 1860s and thereafter.

In retrospect, perhaps the ultimate reason for the decline of the British industry and the success of the German industry is to be found in the contrasting attitudes of the two societies toward science, education and their roles in the industrial well-being of the nation. Ivan Levinstein, that perceptive observer of the industrial decay that infected Britain in the latter part of the 19th century, best expressed this thesis in an address given in 1886 (12):

> The development of industrial enterprise in this country has for the last 30 years been practically confined to cotton, wool, iron and coal, to the lamentable neglect of other industries of apparently minor importance, while the chemical industries have been left in the hands of a few who - often more by good luck than through intelligent and economical management or scientific attainments, but aided by the natural wealth of the country - have carried on the business more or

> less successfully, whilst outside of these few the general public was in profound ignorance of industrial chemistry. Hence the total want of enterprise in this direction on the part of the nation, owing to an insufficient appreciation of the importance of the chemical industries; the consequent apathy and the absence of any intimate connection or intercourse between our scientific men and our manufacturers; and, finally, the very great facility with which fortunes had been made in years gone by in what were then considered staple industries.

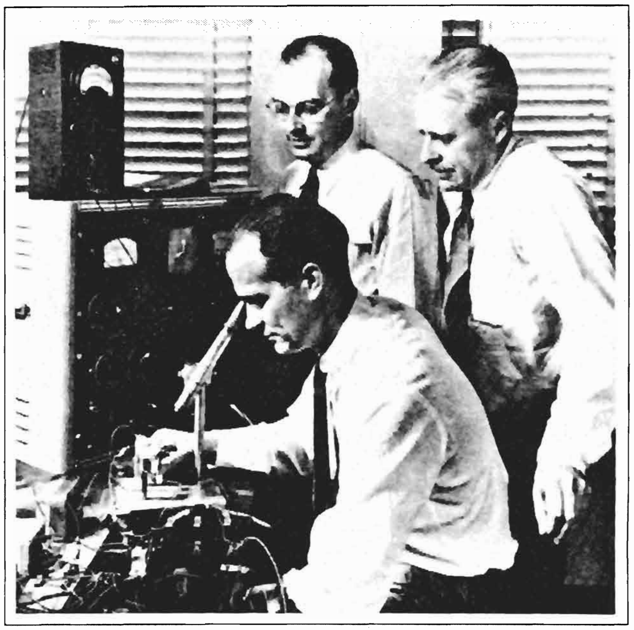
Certainly just the opposite characterized the newly emergent united German nation (13).

Turning to our contemporary analogy, we will now review the American semiconductor industry.

The initial discoveries and commercialization in semiconductors were a purely American achievement. In 1947 William Shockley (b. 1910), John Bardeen, (1908-1991) and Walter Brattain (b. 1902) at Bell Laboratories produced the first transistor which gave birth to the industry. The transistor allowed for the magnification of electronic messages using less current and producing less heat than the conventional vacuum tube. The longer life, smaller size, and greater reliability of this device led to its rapid commercialization after the initial problems in manufacturing were overcome. By 1956 there were already 20 companies making transistors, all of them located near Palo Alto, California in what was to become known as "Silicon Valley". This concentration was the result of William Shockley starting his own company after leaving Bell. Shockley had been raised in Palo Alto and had attended Stanford University. The university had started a research park on its property, and also Arnold Beckman was willing to invest in Shockley's company (14). Shockley hired eight very promising young men from the east coast who went on to found such companies as Intel, Fairchild Semiconductors, National Semiconductors, and Advanced Microsystems.

During the early years of development, 1947-1958, the American semiconductor industry was the world leader in both innovations and production. The industry was dominated by large vertically integrated producers, like IBM and AT&T, but merchant firms, like Texas Instruments and Fairchild also entered the market during the 1950s. Merchant firms sell their entire production on the open market. It is important to note that these two merchant producers were among the most important contributors to the industry's early growth and technological advance. For example, Texas Instruments came up with the silicon junction transistor (1954), the diffused transistor (1956), introduced the integrated circuit (1958), and Fairchild invented the planar process (1959).

The Department of Defense provided large amounts of money for the early development of transistors, and both the military and NASA stimulated the industry's growth through procurement and contributions to research and development. This provided firms the needed capital to take on high-risk and costly ventures, and created an important market for domestic semiconductors. The result was a greater incentive for firms to innovate and introduce new techniques. Direct U.S. government support for R&D and production refinement between 1955 and 1961 amounted to $66.1 million.



William Shockley (seated), John Bardeen (left) and Walter Brattain (right)

During this same period, the Japanese semiconductor industry consisted almost exclusively of vertically-integrated producers, such as Nippon Electric, Hitachi, Toshiba, Matsushita, Mitsubishi, Sony, and Fujitsu. While the Japanese were generally slow to innovate, Sony in 1955 did introduce transistor radios. From the beginning, the consumer market for electronic goods was the principal market for semiconductors. Japanese exports to the United States of transistor radios and black and white television receivers grew rapidly in the 1950s and early 1960s. By 1958, the Japanese had already become the second largest producer of semiconductors in the world, but the U.S. maintained an enormous lead over all other countries. Both the U.S. and Japanese semiconductor industries were in a constant trade surplus during this period.

While the Japanese government did not provide direct aid to the industry, it did enact policies aimed at supporting the industry's growth. The government regulated foreign investment; it protected the infant industry from entry by foreign firms; it encouraged cross-licensing agreements with U.S. companies; and it ensured that Japanese firms had to hold over 50% of the capital in joint ventures. Thus, Japanese firms had sole access to the domestic market and could take advantage of the low cost of labor.

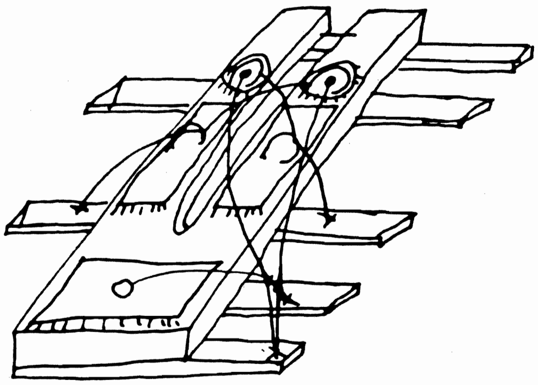
In 1958, a new period in the semiconductor industry began with the introduction of the integrated circuit by Texas Instruments. An entire circuit could now be placed on a silicon wafer. The demand for digital integrated circuits grew rapidly due to their use in computers and telecommunications. The planar process (1959) allowed integrated circuits to be produced by means of large-scale production techniques, thereby lowering production costs and improving reliability. Because the process could only be applied to integrated circuits made of silicon material, silicon replaced germanium as the primary material used for semiconductor devices.

If we consider the period from 1958-1971 (1971 being the year the microprocessor was produced), the U.S. remained the largest producer and consumer of semiconductors in the world. For instance, in 1969, 55% of the world's semiconductors were supplied by the United States (15). The U.S. also remained the world's leading innovator, with merchant producers like Texas Instruments and Fairchild, along with Motorola, holding the largest shares of the U.S. semiconductor market (17%, 13%, and 12% respectively, in 1966).

Military and space procurement was largely responsible for the expanding market in integrated circuits during the 1960s. Of course, the rapid growth in computer demand for both public and private (business and consumer) applications was also a major factor in the growth of the semiconductor industry. Some firms, like IBM, became captive producers, developing semiconductor components for in-house use only. But many new producers entered the computer market, and this resulted in a growing demand for integrated circuits.

The Japanese had devoted considerable amounts to R&D on integrated circuit technology, beginning as far back as 1960. But mass production of integrated circuits lagged behind the U.S. industry because the Japanese remained committed to the use of transistors for their consumer electronics market. Indeed, large imports of integrated circuits into Japan created a trade deficit in semiconductors after 1967; however, this was short-lived. During the 1960s the computer market in Japan was small in comparison to the consumer market, so there was no great demand for integrated circuits for use in computers. This was to change in the 1970s. The government during the 1960s protected the Japanese semiconductor market with high tariffs and by limiting American investments. Only Texas Instruments was allowed to open a plant in 1968. But even then, it had to enter a joint venture with Sony, where Texas Instruments could only hold a 50% share. Further, licenses to produce integrated circuits had to be given to NEC, Hitachi, Mitsubishi, and Toshiba, besides Sony. Also, Texas Instruments could not hold larger than a 10% share of the Japanese market. By protecting its two infant industries - computers and semiconductors - the Japanese laid the groundwork for successful competition with the U.S. in the 1970s and 1980s.

In 1971, Intel introduced the microprocessor, and the period of large-scale integration began. A microprocessor is a single integrated circuit chip which is capable of performing all the central processing unit functions of a computer. When combined with memory and input-output circuits it becomes a microcomputer. World demand for semiconductors grew at an 11.8% annual rate between 1973 and 1982, with the demand for integrated circuits growing at a 15.7% rate. Integrated circuits encompass a wide range of product types, including logic devices, memories, and microprocessors, which has allowed the United States and Japan to compete in a number of different areas.



Jack Kilby's original 1958 drawing of the first integrated circuit

While most innovations in the semiconductor industry still occurred in the United States, by the early 1980s the American industry was faced with a highly competitive Japanese industry. The Japanese had made progress in both product and process technologies and were challenging the U.S. industry in specific product memory chips. By 1978, the U.S. had a trade deficit in semiconductors, while the Japanese found themselves with a growing surplus. Due to the increasing role of semiconductor technology in the electronic and computer industries, as well as the importance to national security, the following discussion will center on how the Japanese came to challenge U.S. dominance in semiconductors.

The Japanese have always been quick to copy or adapt new technology and products, and to foresee the marketing possibilities of semiconductors. For example, during the 1970s, while the American industry first developed metal-oxide semiconductor technology and produced watches and calculators with these circuits, it was the Japanese who saw the potential and moved rapidly to take advantage of these burgeoning markets. Furthermore, the Japanese industry has introduced new products, such as high electron mobility transistors, optical fibers, and long-wavelength semiconductor lasers.

Japanese semiconductors are produced not by relatively small merchant producers, but mostly by large electronics firms manufacturing consumer products, computers, etc. These vertically integrated producers can raise capital more easily and at lower cost than can a smaller, specialized firm, and some of their semiconductor products are then allocated for end-product use.

The growth of the computer industry in the 1970s stimulated demand for digital integrated circuits and particularly for memory devices. Computer firms, like Hitachi and NEC, integrated vertically into the production of memory devices. The data in Table 2 compare the position of the Japanese versus the American semiconductor industries through the early 1980s in terms of memory chips (16). In the early 1980s, four of the ten major semiconductor firms in the world were Japanese, with NEC and Hitachi ranked 3rd and 4th in 1982 in terms of world market share. In 1989, six of the top ten were Japanese (NEC, Tashibu, Hitachi, Fujitsu, Mitsubishi, and Matsushita) and only three were American (Motorola, Texas Instruments, and Intel). In the same year, the U.S. had a 35% share of world semiconductor sales, while Japan had a 52% share; also the Japanese semiconductor market had overtaken the U.S. market and was now the largest in the world. Even in the area of microprocessors, peripherals and microcontrollers, seven Japanese firms rank among the world's top ten suppliers (1987) (17).

What are some of the factors responsible for the growth of the Japanese semiconductor industry? Perhaps the foremost factor is that by the early 1970s the Japanese had a consistent, well-coordinated industrial policy. The Japanese Ministry of International Trade and Industry (MITI) was responsible for creating and implementing this cohesive industrial policy. The semiconductor industry was designated a strategic industry deserving of support. There has never been such a policy in the United States or, as we have seen, in Britain in the 19th century.

By providing money for R&D, restricting foreign imports, and emphasizing the development of the computer and telecommunication industries, domestic semiconductor production became highly successful. MITI provided interest-free loans to help develop "very large system integration" technology, and helped coordinate joint R&D ventures among Japanese firms. Research projects are ranked according to priority; only those projects deemed feasible and essential to Japan's technological development are undertaken. The policy is formulated in close consultation between industry and government, and its goals are dependent upon both technological and commercial requirements. Since the 1970s some $1 billion has been allocated to various research projects. Besides direct subsidies, the Japanese have benefited from tax credits for research, tax incentives for investment, loans to high-priority industries at lower than market interest rates, import duties, quotas, and controls on foreign investment and technology acquisitions.

Table 2. Japanese share of world computer memory chip market

Chip Type	Date	Percentage
1K RAM	early 1970s	0
4K RAM	mid 1970s	12
16K RAM	1979	40
64K RAM	1981	70
64K RAM	1984	54
256K RAM	1984	90

It should be noted that tariffs and other restrictions on foreign investment were all but eliminated by 1987, due in large part to U.S. pressure for the Japanese to open their domestic market. Also, government financing has declined in recent years, as private banks and institutions became eager to loan needed funds to semiconductor firms. Therefore, today's industrial policy in Japan is directed primarily at improving the competitive position of the industry, and seeing to it that the semiconductor industry can respond to a changing economic and technological environment.

In terms of technology, while virtually all of the breakthroughs in the semiconductor area were as a result of U.S. firms engaged in research and development, the Japanese have made important strides in process technology as did the Germans in the dye industry in the 19th century. For example, the Japanese firms moved towards greater automation well before American firms, the results being lower costs and greater quality and reliability of semiconductors. Due to Japan's employment practices, which ensure lifetime employment, workers more easily accept automation as a way of increasing productivity, unlike U.S. workers who see automation as a threat. Thus, Japan has been able to achieve a quality edge over the U.S. in production, assembly, and testing. Given the long-term relationship of the Japanese worker to the firm and his commitment to the firm's success, this has led to better communication between labor and management, managerial efficiency, teamwork, and higher productivity.

For a number of years, American firms have accused Japanese producers of predatory pricing, that is, "dumping" semiconductors, especially memory chips, in the United States at prices below per unit average costs. The result has been to drive American firms from specific product markets, and in some cases out of business. However, this is difficult to prove, as the low prices may be justified due to the so-called learning curve. Many British manufacturers were also driven out of business due to cheap German imports. In 1986 American firms did accuse the Japanese of pricing below cost, and the Japanese agreed to raise semiconductor prices. However, in 1987 the Japanese were accused of going back on the agreement.

We need to make one final point on technology. A great deal of Japanese success can be attributed to licensing agreements and second sourcing with U.S. companies. This is where Japanese manufacturers are licensed to produce and sell U.S. designed devices (memory chips, microcontrollers, etc.) so as to guarantee customers adequate supplies at fair prices, and to better market a device. The consequence, however, has been to allow the Japanese to produce products of higher quality and at lower cost than that of the U.S. and thus improve their own competitive position.

The savings rate in Japan has remained consistently higher than the U.S., well over 20% of GNP in the postwar years. Coupled with a cost of capital almost three times higher in the U.S. than in Japan, American companies are at a disadvantage. The prices of U.S. products are higher and the return on investment lower than in Japan. Historically, the U.S. firms have depended on equity financing (stock issues), while the Japanese have chosen debt financing (bank loans and corporate bonds), as a means to raise capital. From 1967 to 1983, the average debt-market value ratio was 26% in the U.S. and 63% for the Japanese. American companies (including all industries) invest about 1.8% of GNP; the Japanese invest 2.8% of their GNP. In 1987-1988, U.S. spending on R&D was 3%. For Japan it was 11%. In fact, five countries spent more of their GNP on R&D than the United States. For example, from 1972-1980, U.S. semiconductor companies spent between 6 and 12% of their revenues on R&D. Japanese semiconductor firms, from 1973-1978, spent 16.9% of their integrated circuits revenue on R&D. U.S. dependence on equity financing causes companies to put greater emphasis on short-term earnings and risk-avoidance. Japanese companies, on the other hand, are willing to take risks on new investment in physical capital, and can sustain short-term losses in order to attain a larger market share. As was seen earlier, a similar difference in German versus British attitudes towards long-term investment contributed to the decline of the British dye industry.

How has the U.S. responded to Japan's challenge? American semiconductor companies are working towards achieving improved technological and cost efficiencies, capital improvements, and greater spending on R&D in hopes of developing a new generation of semiconductor products. Areas of research include gallium arsenide semiconductors, superconductivity, and important developments in microprocessors. American firms have restricted second source production by Japanese firms, particularly in microprocessors, in order to increase profits.

Can the U.S. compete successfully in the future? Will history repeat itself? It may, unless industry and government form a coordinated approach in which the semiconductor industry can set long-term goals and where the government provides subsidies and tax incentives for R&D and capital formation. An investment tax credit and reduction in capital gains taxes could stimulate industry growth. Trade sanctions can also be a useful tool, if used sparingly in order to avoid a trade war with Japan. Above all, U.S. firms must expand their technological base and protect new technologies from infringement by Japanese companies. Only by maintaining a technological edge can American semiconductor firms achieve success, for "... the Japanese have begun an initiative to build a superior technological base, which, if it comes even close to the success of their manufacturing programs, could make them an unbeatable competitor" (17).

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THE FIRST HALF CENTURY OF CHEMISTRY AT CLARK UNIVERSITY

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In 1987 Clark University observed the centennial of its founding, which was instigated by Jonas Clark (1815-1900), a successful businessman in Worcester, Massachusetts, where the institution was to be located. It was created strictly as a graduate school, with programs first set up in physics, chemistry, mathematics, biology, and psychology. G. Stanley Hall (1846-1924), holding a Ph.D. in psychology from Harvard, was appointed the first President (1).

Clark University sprang into being just as the 19th century was coming to an end. This coincided with the peak of activity in the traditional sciences, including chemistry, in Germany, whereas these fields were still in the early stages of development in the United States and Canada. Thus it is understandable that the graduate programs at Clark were tailored after the German model. President Hall himself had spent time in Germany before beginning his Ph.D. His first action, on being chosen to head up the new university, was to sail for Europe, where he spent six months establishing contacts with German professors and evaluating young Americans who were studying there. Both Hall's personal experiences in Germany and his hiring of German-trained faculty in all of the disciplines contributed to the molding of the character of the early Clark graduate program. It was similar to the program in chemistry established by Ira Remsen at Johns Hopkins, where Hall had held the position of Professor of Psychology and Pedagogy before his selection as the first president of Clark.

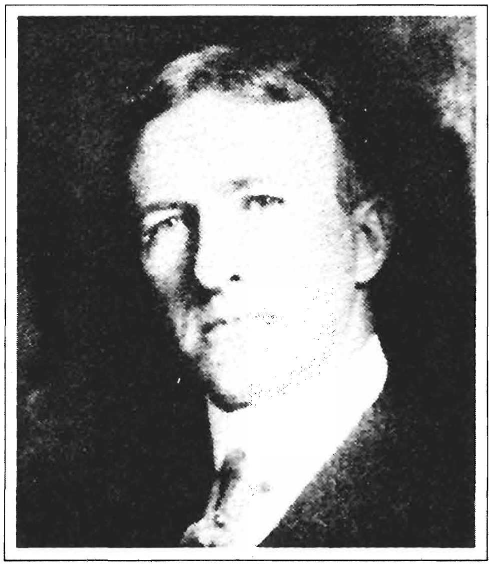
The chemical laboratory at Clark, circa 1890

John Ulric Nef

Although the university had its beginning in 1887, the chemistry department came into existence slightly later. By 1890 the chemistry laboratory was completed and the first faculty member to head up chemistry, Arthur Michael (1853-1942), was appointed in 1889. He had spent time in several German university laboratories, though he never earned an advanced degree. However, his tenure at Clark was fleeting, lasting only a few months in the fall of 1889, not even long enough to make the listing in the university catalog. The reason for his abrupt departure was the refusal of Jonas Clark to allow laboratory privileges for Michael's wife, also a student of chemistry. This placed President Hall in an awkward position, for he had included this promise as one of the conditions of Michael's appointment. Michael simultaneously held a teaching position at Tufts University, where he taught intermittently during the period 1880-1907, after which he became professor of organic chemistry at Harvard, though most of his work was done in his private laboratory in Newton, Massachusetts.

Swiss-born John Ulric Nef (1862-1915), a doctoral student of Adolf Baeyer in Munich, was Michael's successor. He and Michael were to have disagreements on experimental results a few years later. Nef remained at Clark for only three years, spending the remainder of his career at the University of Chicago. He had two Ph.D. students at Clark: Thomas H. Clark (1892 - no relation to Jonas) and John L. Bridge (1894). Both carried out research on benzoquinones. Curiously, Bridge's thesis, which was completed at Chicago, was written in German and carried the title "Ueber die Aether des Chinonoxims." One of Nef's first Ph.D. students at Chicago, Adolf Bernhard, had been a graduate fellow at Clark in 1892 and followed Nef to Chicago.

Morris Loeb (1863-1912), with a doctoral degree from Berlin under August W. Hofmann, served as lecturer at Clark from 1889-1891 and so overlapped with Nef. He then became Professor of Chemistry at New York University, a position which he held until his early death at the age of 49 (2). With the abrupt departure of Nef, Samuel Mulliken (1864-1934), already holding the position of graduate fellow (1890-1892), presided over the chemistry program briefly between 1892 and 1894 under the rubric of "Instructor and Acting Head". A doctoral student of Johannes Wislicenus at Leipzig, Mulliken left for MIT in 1895, where he remained until his death. His son, Robert Mulliken (1896-1986), received the Nobel Prize in Chemistry in 1966. While at Clark, Mulliken directed the Ph.D. thesis of Julius B. Weems (1894) on a project involving Kolbe electrolysis.



Benjamin S. Merigold

Martin André Rosanoff

Percy N. Evans (1869-1925), another recent doctoral student from Leipzig, holding the position of honorary fellow for 1894, might well have succeeded to the head of chemistry, had the program continued. But a crisis brought on by a severe shortage of funds and by what some viewed as serious mismanagement by President Hall led to a discontinuation of instruction in chemistry. Instead Evans spent the rest of his career at Purdue.

The early period of chemistry at Clark had lasted only five years. In that time five faculty or staff had been engaged, and three Ph.D. students had emerged. The break in the chemistry program lasted for ten years. No chemistry faculty were listed in university catalogs from 1895-1902. The first chemistry faculty designated as "undergraduate" appeared in the 1902 catalog, but graduate faculty emerged again only in 1904. Charles W. Easley (1876-1929), who held A.B. and A.M. degrees from Dickinson College, was appointed instructor of undergraduate chemistry in 1902 and remained at Clark until 1908, when he had completed his own Ph.D. He was joined in 1903 by Benjamin Shores Merigold (1873-1962). Merigold held A.B., A.M. and Ph.D. degrees from Harvard, where he had been a student of Theodore W. Richards. First listed as graduate instructor and then as undergraduate assistant professor, he had been an instructor from 1900-1903 at Worcester

Polytechnic Institute. He spent the rest of his career at Clark, retiring in 1946.

Though Merigold was already on the scene when the "graduate revival" began in 1907; and though he had both seniority and a Ph.D., he was not chosen to head chemistry. Instead the appointment was given to Martin André Rosanoff (1874-1951), a native of Russia, who had earned an undergraduate Ph.B. at New York University, very likely under the tutelage of Morris Loeb. He had spent some time abroad in Berlin and Paris (under Charles Friedel) and then became assistant to James M. Crafts at MIT. He earned no advanced degree but was awarded an honorary D.Sc. by New York University in 1908. He headed the Clark Chemistry Department for seven years (1907-1914).

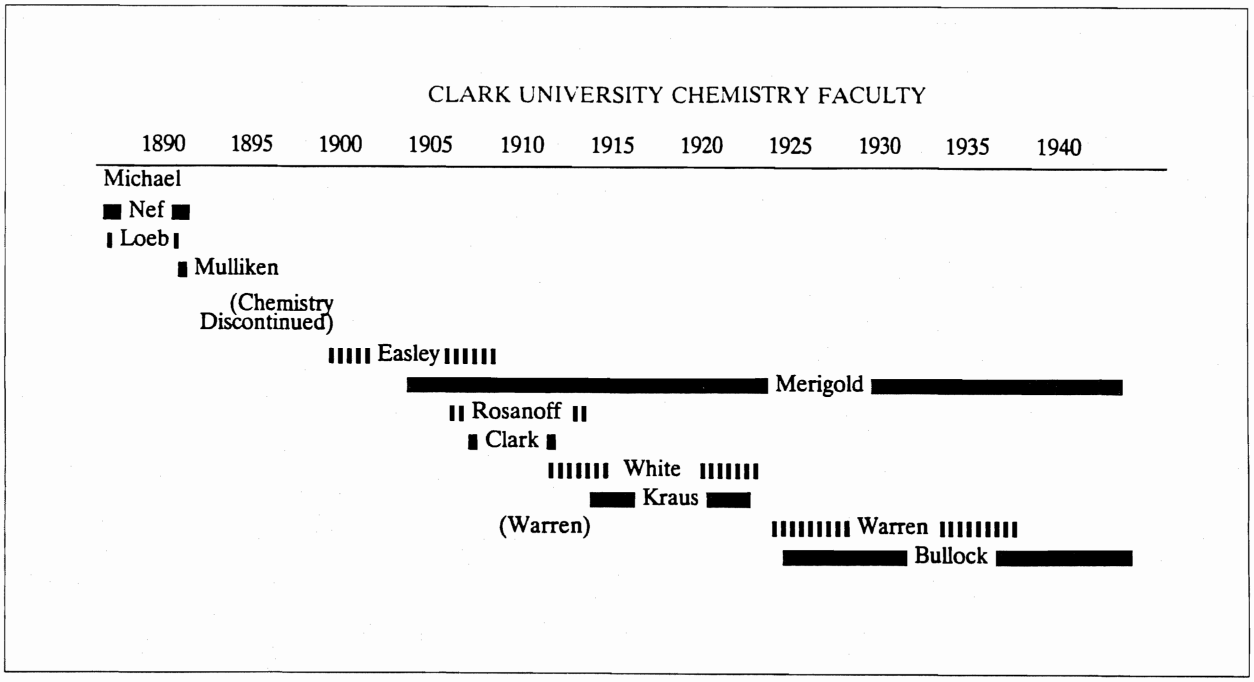
The result was a renaissance in chemistry for Clark. Rosanoff directed the dissertations of all eight of the students who earned Ph.D. degrees during his tenure. Though several of the dissertations concerned classical topics in physical chemistry, such as the determination of vapor pressures and dielectric constants, others dealt with what might be called physical organic chemistry - notably, the role of catalysis in esterification and in the inversion of sugars. In his annual report to the president for 1910-1911, Rosanoff described his work with C. W. Bacon, on "a complete solution of the eighteen-centuries-old problem of fractional distillation", as "the most important result of the year and probably of many future years." In the same year he was awarded the Nichols Medal by the New York Section of the American Chemical Society. His professional accomplishments notwithstanding, Rosanoff was fired in 1914 because of difficulty in getting along with other faculty and administrators. The rest of his career was spent at the Mellon Institute, at Duquesne University, and as a private consultant (3).

Other faculty were gradually added to the Department during Rosanoff's tenure. Robert Harvey Clark (1880-?), a Canadian with a Ph.D. from Leipzig under Arthur Hantzsch, held the positions of docent, acting assistant professor, and finally assistant professor during the 1910-1911 term. He was followed the next year by William Homer Warren (1866-1954), who, like Merigold, had received all of his chemical training (through the Ph.D.) at Harvard, where his mentor was Charles L. Jackson. After a varied industrial and academic career, Warren returned to Clark in 1925 as professor of organic chemistry and remained until his retirement in 1937.

The period of Warren's absence from Clark was filled by George Frederic White (1885-1929), who rose through the ranks to become professor of organic chemistry, retiring in 1925. White, a Johns Hopkins Ph.D. under Harry C. Jones, coauthored a laboratory manual in inorganic chemistry in 1911 (4) and authored a book on qualitative chemical analysis in 1916 (5). He also published about a dozen papers, either from Woods Hole or Clark, some coauthored by Clark students, and one in collaboration with Charles Kraus (see below).

Additional teaching during the Rosanoff era was done by MIT faculty members Arthur A. Noyes (1866-1936) and James F. Norris (1871-1940), who were listed in Clark catalogs in the 1912-1914 period as nonresident lecturers.

Rosanoff was followed as head by Charles A. Kraus (1875-1957), a Ph.D. student of A. A. Noyes at MIT. During his tenure at Clark (1915-1924), he supervised the thesis work of 17 Ph.D. students, mostly on the behavior of metals and organometallics in liquid ammonia. Master's degrees were


CLARK UNIVERSITY CHEMISTRY FACULTY

awarded to many students, several of them remaining at Clark to complete the Ph.D. When Kraus left Clark to head the department at Brown University, several students went with him to complete their degrees in Providence. Kraus was eventually the recipient of the Nichols, Gibbs, and Priestley medals and served as President of the ACS in 1939.

In 1915, during the interim period following Rosanoff's abrupt departure and before Kraus arrived, a Ph.D. was completed by Elmer A. Harrington, a former assistant in chemistry, who acknowledged a Professor Webster in Physics as having suggested the project, which dealt with the dielectric constants of aqueous solutions.

B. S. Merigold, who had served on the chemistry faculty longer than any of the remaining colleagues, finally succeeded Kraus as Director of Laboratories in 1926, a position he retained until his retirement in 1946. There is no indication in either the Clark Archives or *Chemical Abstracts* that Merigold directed research students or authored chemical publications.

Following the departure of President Hall in 1920, there was a change in the character of the chemistry department. Though no Ph.Ds were awarded between 1926, (i.e., shortly after Kraus's departure) and 1934, the number of A.M. degrees in chemistry continued to average four per year throughout this period. In the next seven-year period (1934-1940), only eight Ph.Ds were awarded (and only in four of those years), but 20 students earned A.M. degrees. Research was revived somewhat in the period when Warren and Jesse L. Bullock (1889-?) were members of the chemistry faculty. Between them they directed the dissertations for all eight Ph.Ds granted in the 1930s. After earning his A.B. at Harvard, Bullock had spent ten years in industry before joining the Clark faculty in 1926, where he remained until his retirement in 1959. He did not complete his doctoral degree at Harvard until 1932.

Where did Clark graduate students originate? Because it was founded as a graduate institution, the early students necessarily came from elsewhere. The three earliest Ph.Ds had earned baccalaureate degrees at Worcester Polytechnic Institute, Wesleyan University, and the University of Maryland. Rosanoff's doctoral students came from City College of New York, New York University (his own alma mater), Dickinson College, Barnard College, and Kentucky State University, as well as Clark. After the chemistry A.B. was introduced in 1908, Clark undergraduates often continued as graduate students. Indeed this became the common pattern during the Kraus era, with many A.B. chemistry majors continuing at Clark to complete the Ph.D., though about half terminated at the A.M. Interestingly, a pipeline from Kalamazoo College also apparently developed, since one Clark Ph.D. in each of the years 1920, 1921, 1922, 1924, and 1926 was a Kalamazoo undergraduate. Almost without exception, the A.M. preceded the Ph.D., the usual time lapse between the two degrees being between two and three years (6).


Charles A. Kraus

Only two women earned graduate degrees from Clark prior to 1940. Lillian Rosanoff Lieber, sister of Martin Rosanoff, completed her Ph.D. under her brother's direction in 1914 with a dissertation entitled "Theory of the Catalysis of Sugar Inversion by Acids." She became a research fellow at Bryn Mawr (1915-1917) under J. Barnes, and an instructor of physics for one year each at Wells College (1917-1918) and at Connecticut College (1918-1919). She was promoted to Assistant Professor after one year at Connecticut College but resigned in August of 1920. Lillian eventually became Professor of Mathematics at Long Island University, Director of the Galois Institute of Mathematics and Art, and author of a large number of popular books on mathematics and relativity theory, all of them written in free verse and illustrated with abstract cartoons by her husband, Hugh Gray Lieber. In 1955, she published a volume of her brother's collected papers on chemistry containing a rather uninformative introduction, also written in free verse (3).

A second woman, Marion Jeanette Sears, earned an A.M. in 1936. Arthur Michael's wife, Helen Abbott, whom he married in 1889, the same year he was appointed at Clark, might have been the first woman graduate, had she been allowed laboratory space.

An evaluation of the later careers of all the Clark graduates prior to 1940, though a worthy goal, is well beyond the scope of this paper; and a few examples will have to suffice instead. The first Ph.D., Thomas H. Clark, was briefly an instructor at Tufts and Clinton Liberal Institute. In 1899 he was appointed Instructor in Chemistry and Physics at Plymouth State College, New Hampshire, a position he held for four years. John L. Bridge (Ph.D., 1894) earned an M.D. at Harvard and became a physician in Connecticut. Julius B. Weems (Ph.D., 1894) served as Professor of Agricultural Chemistry at Iowa State from 1895-1904. In 1915 he became Chief Chemist for the Department of Agriculture in Richmond, Virginia, where he remained until his death in 1930.

Charles Easley, Rosanoff's first Ph.D. student at Clark, served on the chemistry faculty at University of Maine, from 1909-1919, and then became Professor of Chemistry at Syracuse University. One of Kraus's doctoral students, Charles B. Hurd, after one-year appointments at Colby College and Trinity College, began a career at Union College, where over the next 30 years he directed an outstanding undergraduate research program in colloid chemistry (7).

This historical account of the evolution of the chemistry department at Clark University has focused on the first 50 years, for which archival information was examined. Despite a turbulent beginning a century ago, when the stability and continuity of the department were severely threatened, the department went on to enjoy periods of professional activity for which it has earned justified recognition.

References and Notes

Acknowledgments: Information on the faculty and students in chemistry at Clark has come from two sources: the excellent recent history of Clark University by William A. Koelsch (1); and the Clark University Archives. I am grateful to University Archivist Stuart W. Campbell and his assistant, Betty A. Bacinskas, for their willingness to provide a roster of chemistry faculty and staff from university catalogs during Clark's first 30 years. Information on students was acquired by searching a student file compiled by Professor Koelsch, from commencement programs, and alumni class lists.

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3. L. Lieber, ed., *Collected Works of Martin André Rosanoff*, Galois Institute, New York, 1955. If this collection is accurate, it shows that Rosanoff ceased to publish after 1916. The volume also contains an unpublished paper by Lillian and her brother based on her Ph.D. work at Clark.

4. G. F. White and E. C. Bingham, *A Laboratory Manual of Inorganic Chemistry*, Wiley, New York, NY, 1911.

5. G. F. White, *A Laboratory and Class-Room Guide to Qualitative Chemical Analysis*, Van Nostrand, New York, NY, 1916. A second edition appeared in 1920.

6. A complete listing of all graduate and undergraduate degrees in chemistry given by Clark for the period 1892-1940 is available from the author upon request.

7. W. J. Hagan Jr., "Charles Hurd and Colloid Chemistry at Union College, 1923-1959", *J. Chem. Educ.*, **1988**, *65*, 191-193.

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CHEMICAL INDUSTRY IN COLONIAL VIRGINIA

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In the latter part of the 16th century many Englishmen advocated the founding of a colony in North America, and a number of reasons were put forward. These ranged all the way from extending Christianity to strengthening the defenses of England against Spain. Probably foremost in the minds of the members of the London Company was the discovery of gold and of a direct route to the South Seas, but it was also hoped that the new country would supply England with tar, pitch, rosin, glass, soap-ashes (potash), copper, iron, steel, and wine.

English settlers first landed at Jamestown in May, 1607. Early in 1608 the "first supply" of about 100 additional settlers, including a perfumer, was landed. In the fall of 1608 the "second supply" - including eight Dutchmen and Poles - was landed. The Dutch and Poles were sent over to establish the glass and naval stores industries. Evidently they got right to work, because a few weeks later samples of pitch, tar, glass, frankincense and soap-ashes (potash) were shipped to England. These industries did not survive long, principally because the colonists were too busy fighting off starvation and the Indians. Captain John Smith (1580-1631) did not approve of attempting to establish industries before sufficient food and shelter had been provided for the colonists. He asked for carpenters, masons, farmers, fishermen, blacksmiths and common laborers.

About the time the Pilgrims were landing in New England, the colonists in Virginia were attempting to revive the glass works. In 1621 six Italian glass workers came over, primarily to make beads for use in the Indian trade, but also to produce bottles, table glass, and other glassware for sale in England. Great precautions were taken to keep the process secret, because the beads were the money used in trading with the Indians and the Company was anxious to keep their value up. It was emphasized especially that the Virginians must not know the process. The glass works, located at Jamestown, escaped the general destruction accompanying the massacre of 1622 and continued in operation until 1624. At that time the Italian workmen, who were anxious to return to Europe and who had been sabotaging production by means of slow-down tactics, wrecked the plant and broke the furnace by striking it with an iron bar. That ended the manufacture of glass in that plant. The original site of this glassworks at Jamestown was located in 1931.

From the beginning, many people had been interested in locating iron ore and setting up plants for its reduction. One of the strongest motives for colonization was the expectation that Virginia would furnish England with plenty of cheap raw iron. Early on, Smith recognized the adaptability of the colony to iron manufacture, and in 1609 a quantity of ore was shipped to the mother country. About ten years later the first real attempt was made to manufacture iron in Virginia. An anonymous benefactor had given the London Company the sum of £550 to be used in the education of Indian children as Christians. The Company was anxious to escape this obligation and persuaded a private group of investors, known as the "Southampton Adventurers", to accept and administer the gift. This group hit upon the idea of adding some of its own money and using the whole amount to set up an iron works and then spending the return pro rata of the gift on Indian education. Laborers and experienced iron workers were sent over, a successful mine was opened, and the works was built on Falling Creek, seven miles below the falls of the James River. In 1621 the cost of setting up the iron works was calculated to be £4000-5000. By 1622 it was confidently expected that within a few months the works would be capable of shipping large quantities of raw iron to England. The great Indian massacre of that year ended the attempt. All of the workmen, managers and their families - except two children - were killed, and the machinery was broken up and thrown in the river. It was claimed that the only practical return on the enormous investment was an iron shovel, a pair of tongs and a bar of iron. The Southampton Adventurers were determined to try again, but before they could act, Virginia became a royal colony. No sustained attempt was made to produce iron until about 100 years later, when Alexander Spotswood (1676-1740) started building furnaces.

Captain John Smith

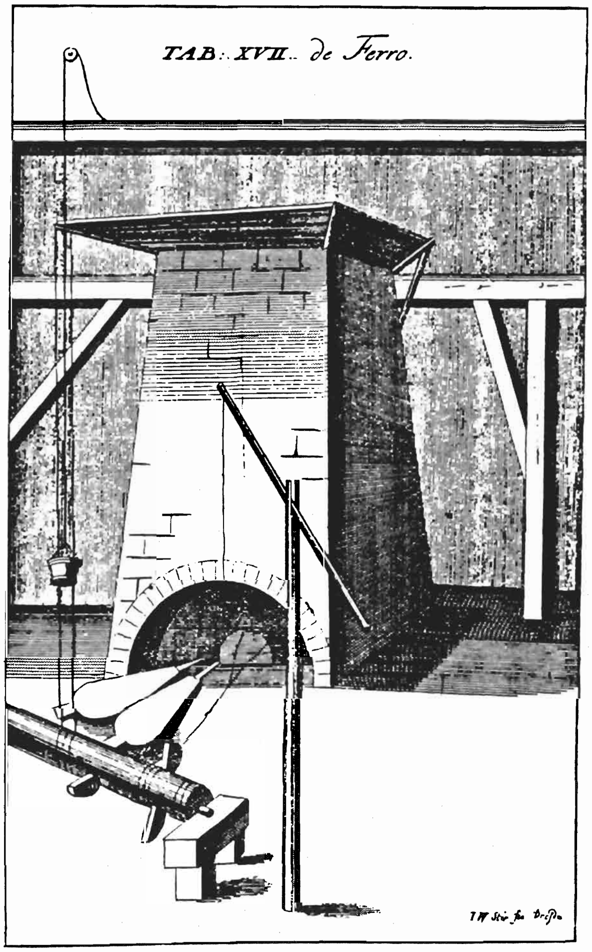
A late 16th-century glass furnace

The cultivation of tobacco was started in 1612 by John Rolfe (1585-1622), the husband of Pocahontas, and the tobacco rapidly assumed a dominant position in the economy of the colony. It was a fine source of revenue for both the planters and the home government. The Virginians became an agricultural people by force of circumstances - the power of the English government was used to divert their attention from manufacturers and toward the cultivation of tobacco. By 1720 the Privy Council was definitely encouraging tobacco and forbade the colonists to apply their labor to other produce or manufactures. It rejected a Virginia act for the advancement of manufactures.

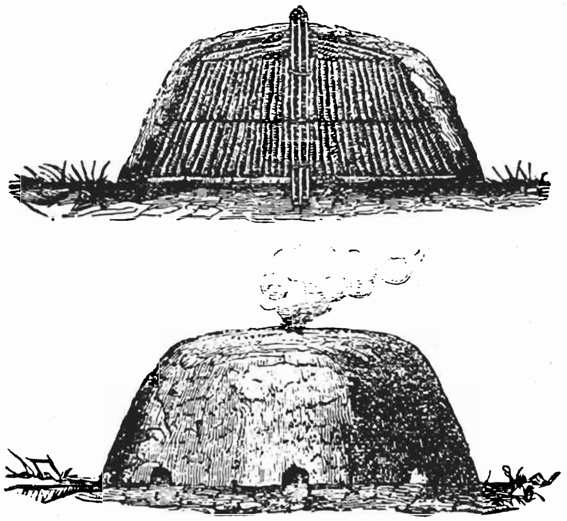
However, early in the 18th century, Spotswood revived the iron industry and by 1732 there were three blast furnaces and one air furnace in operation, but no forge. About 100 common laborers, including women cooks, were required to run a charcoal blast furnace. In addition, several skilled workmen were employed, including a founder, a collier (who made charcoal), a miner, a clerk and a stock-taker. The founder, collier and miner were paid according to production. A great wheel, 26 feet in diameter, turned by water power, worked the two pairs of bellows that blew the furnace at Fredericksburg - the air was not preheated. A blast furnace could run about 20 tons per week, and 800 tons per year was considered a good output. The expense of carting the ore from mine to furnace - even for one mile - was a heavy one, as was the expense of carting the pig iron from the furnace to the docks. It was customary to use eight oxen to draw a 3000 pound load. At the air furnace at Massaponax, Spotswood melted pig iron and cast pots, skillets, chimney backs, plates for hearths, andirons, fenders, mortars, etc. for sale in the colony.

The Principle Company of Maryland owned a furnace, built in 1726, in Stafford County, Virginia, on a plantation of Augustine Washington, the father of George. In 1750 Virginia and Maryland together exported 2400 tons of pig iron to England, of which this furnace produced one-sixth.

In 1768 three Baltimore capitalists bought land in Albemarle County and started the Albemarle Furnace Company with a capital of £2000. Thomas Jefferson was interested to the extent of £100. Three furnaces were built in the county. It is quite possible that this enterprise was in anticipation of the Revolution.



An early 18th-century blast furnace



A setup for the manufacture of charcoal, pitch and tar

In the Shenandoah Valley an iron industry grew up, starting early in the 18th century. German and Scotch-Irish immigrants began coming down the valley, where they found beds of iron ore in the form of hematite. They opened mines, built both furnaces and forges, and began making pig and bar iron and pots, pans and firearms for local use. Many of these small works endured for some time and were famous for their good craftsmanship. There are no good statistics for these young industries until 1781, when Thomas Jefferson stated that two of the furnaces in the valley each produced 600 tons of pig iron a year. Bruce (1b) lists 15 furnaces known to have been in action before the Revolutionary War within the bounds of the present state of Virginia.

Pitch and tar were produced in small quantities during the administration of the Company, several Poles having been brought over for that purpose. It was proposed that apprentices learn the art and that the industry be built up, especially for the benefit of the Royal Navy. However, there is no evidence that these products were made on a scale of importance during the subsequent history of the colony. About 1700 the only place in Virginia where pitch and tar were produced in considerable quantity was in Elizabeth City County and the amount did not exceed 1200 barrels annually. The industry was carried on principally by poor men who owned no slaves and who considered a few dozen barrels per year an excellent output. The method used was crude: first a circular floor of clay was laid down and on this were piled pine logs. These were covered with a layer of dirt and ignited through a small opening left for that purpose. This opening was then closed and the fire left to smoulder. As the tar trickled down the clay floor, it was drained off into barrels by means of a wooden pipe. If pitch was wanted, the tar was boiled in large iron kettles or burned in holes made in the clay. There were many attempts to make potash, and several samples were sent to England, but at no time did the production of this commodity develop into an important industry.

There were scattered attempts to build up a wine industry, with both native and imported grapes. At several times French vine-dressers were brought over for the purpose of establishing vineyards, but for one reason or another they were usually not successful.

Copper and gold deposits apparently were not worked in colonial Virginia. Lead was discovered in Wythe County by a Colonel Chiswell, who worked the deposits until the beginning of the Revolutionary War, when he was arrested for his Tory sympathies.

Other industries included a salt works at Cape Charles on the Eastern Shore, and the cultivation of silk from the mulberry tree. It is said that Charles II at his coronation in 1661 wore a robe and hose of Virginia silk (2).

Generally speaking, Colonial Virginia was an agricultural community. To a large extent, manufactures were still in the handicraft stage, and most goods were produced for local and home use. Many of the colonial industries were carried on in the home. The industrial progress was not great by present day standards, but of course the conditions of pioneer life must be considered.

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1. Sources used in this study: (a) J. C. Ballagh, *The South in the Building of the Nation*, Vol. 5, *Economic History, 1607-1865*, The Southern Historical Publication Society, Richmond, Virginia, 1910. (b) K. Bruce, *Virginia Iron Manufacture in the Slave Era*, The Century Co., New York, 1930. (c) P. A. Bruce, *Economic History of Virginia in the Seventeenth Century*, Macmillan, New York, 1907. (d) M. P. Hull, *Early Glass Making in Virginia*, Jones Printing Co., Richmond, Virginia, 1933.
2. E. F. Smith, "Venable Hall", *J. Chem. Educ.*, **1926**, *3*, 946-949. Smith, in an address given on the occasion of the dedication of Venable Hall at the University of North Carolina on 12 October 1925, tells briefly in two paragraphs something of the chemical industry in Colonial Virginia.
3. W. V. Sessions, "Some Early Industries in the United States", *J. Chem. Educ.*, **1928**, *5*, 922-928. Much of this article deals with other areas of the country and with post-Revolutionary War times, but there is some mention of Colonial Virginia.

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OLD CHEMISTRIES

Thomas Ewell's "Plain Discourses on the Laws or Properties of Matter"

Robert H. Goldsmith, St. Mary's College of Maryland

Thomas Ewell's *Plain Discourses on the Laws or Properties of Matter Containing the Elements or Principles of Modern Chemistry* was published in 1806 for an audience of artisans, farmers and fellow citizens and has been described as a nontechnical presentation of useful chemical knowledge (1). This was the first and only edition of a work which was used primarily in the Southern and Eastern United States in the first quarter of the 19th century (2). Despite the fact that it was intended for popular use, it was also used as a textbook at the College of William and Mary (3).

The book's arrangement and choice of subject matter resemble that found in other chemical publications of this time period, and Ewell admitted that, in writing his book, he had utilized the chemical works of Thomson, Chaptal and Murray, as well as numerous quotations from Accum's works (4). He also provided an extensive outline, placed a list of definitions at the end of the text, and stated that he had utilized as few technical terms as possible, since he felt that the use of such terms was confusing to the average citizen and irrelevant to an understanding of the basic principles (5). The text is also characterized by the lack of utilization of a large number of divisions and subdivisions and the omission of historical background on noteworthy chemists and their discoveries.

Ewell's text is divided into a dedication, a preface, an introduction, 15 chapters (which are called discourses) and a summary. In the dedication the book was inscribed to Thomas Jefferson. The introduction presents Ewell's view of chemistry and its value in society. The first discourse deals with physical and chemical properties, the nature of matter and an introduction to heat. The second discourse presents views of light, galvanism and electricity, while the third discourse describes the composition of the atmosphere and the versatility of water. The fourth and fifth discourses describe the chemical nature and uses of common inorganic compounds and the nonmetallic elements. The sixth discourse focuses on the elementary earths, while the next two deal with the metals. The ninth discourse restricts itself to a description of the nature, production and value of the most important minerals. The properties, growth and identification of vegetable substances are well treated in the next three discourses and the thirteenth and fourteenth do the same with animal substances. The final discourse introduces nutrition and the technology of dye use. The author concludes with a brief restatement of basic principles.

An examination of the textual material reveals that nearly all of the subject matter presented is in accord with prevailing chemical theory. However, there are several items that reflect Ewell's own research efforts and beliefs. Of greatest interest to chemists are his experimental and theoretical objections to Dr. Black's theory of latent heat and his presentation of his own version of the caloric theory (6). In support of his theory, he presented original data from experiments designed to show that, when heat is released or gained, there is an equivalent gain or loss in weight. Ewell asserted that these experiments, which had been originally published in the *Medical Repository* and were later included in a compilation of his works published in 1819, proved that heat was a form of matter (7). Ewell also presented his own viewpoints on electricity and the nature of vegetation, and mentioned experiments he had performed with coal, but without giving any details.

The most interesting aspect of this book is that it is probably the first American-authored textbook designed explicitly for the nonspecialist or the common man. In the preface Ewell makes the following statement (8):

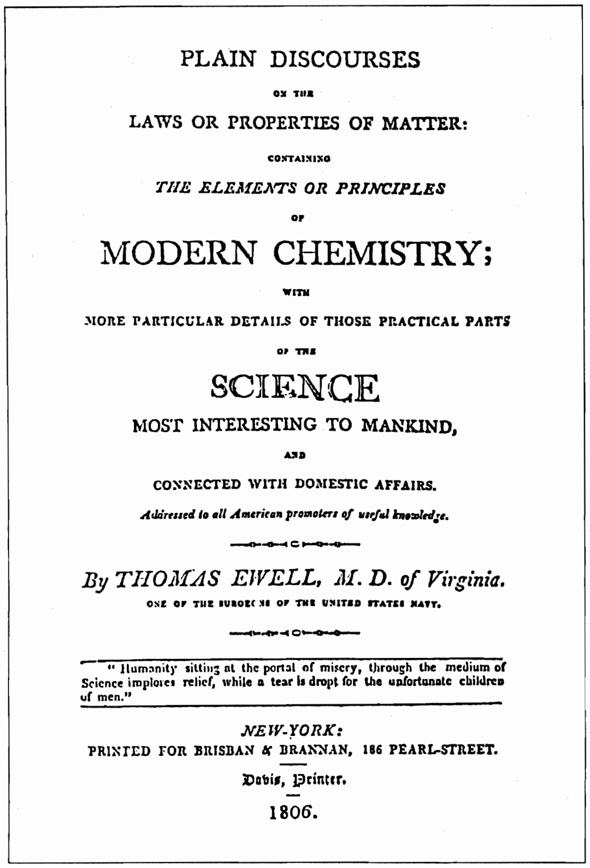
> The following plain work I prepared with a view to lessen the difficulties and to increase the conveniences of the citizens of the United States, by introducing them to a more intimate acquaintance with chemistry of the qualities of the substances around them. The immense advantages, which will result from the general diffusion of such knowledge, are glanced at in the introductory discourse. These advantages, I have indulged in the hope, will lead the respectable farmers and artists, the benevolent editors of publications, particularly the teachers of seminaries, my brethren of the medical faculty, and the intelligent of every denomination, to favor and promote the undertaking.

Support for this approach was given in letter which Ewell received from Thomas Jefferson (9):

> Of the importance of turning a knowledge of chemistry to household purposes, I have long been satisfied. The common herd of philosophers seem to write only for one another. The chemists have filled volumes on the composition of a thousand substances of no sort of importance to the purposes of life: while the arts of making bread, butter, cheese, vinegar, soap, beer, cider and cc. remain unexplained. Good treatises on these subjects should receive general approbation.

Another letter from Bushwood Washington, nephew of George Washington and Associate Justice of the Supreme Court, also endorsed Ewell's approach (10):

> I have long thought that a work upon the plan you suggest was much wanted by those who form the great bulk of readers on chemical subjects. I have not met with a single treatise, which has not appeared unnecessarily obscured by technical terms, which only scholars can understand. They have been more generally addressed to the comprehension of professional and learned men, than to those of the humble walks of life; for whose use this science might be made most essentially to contribute, by adapting it to their capacities and by pointing out the way by which its principles may be applied to the more common arts, in which they are daily employed. You will I think do great good to society and much honor to yourself, by executing such a work as you propose.



PLAIN DISCOURSES
ON THE
LAWS OR PROPERTIES OF MATTER:
CONTAINING
THE ELEMENTS OR PRINCIPLES
OF
MODERN CHEMISTRY;
WITH
MORE PARTICULAR DETAILS OF THOSE PRACTICAL PARTS
OF THE
SCIENCE
MOST INTERESTING TO MANKIND,
AND
CONNECTED WITH DOMESTIC AFFAIRS.
Addressed to all American promoters of useful knowledge.

By THOMAS EWELL, M. D. of Virginia.
ONE OF THE SURGEONS OF THE UNITED STATES NAVY.

"Humanity sitting at the portal of misery, through the medium of Science implores relief, while a tear is dropt for the unfortunate children of men."

NEW-YORK:
PRINTED FOR BRISBAN & BRANNAN, 186 PEARL-STREET.
Davis, Printer.
1806.

This book represents Ewell's attempt to relate the basic ideas of chemistry along with useful chemical information on practical chemical concerns such as gunpowder, glasses, pottery, fertilizers, metallurgy, gilding, inks, sugars, wines and dyes to the nontechnical citizen in the simplest manner possible, and it should be noted that his efforts did receive recognition (11).

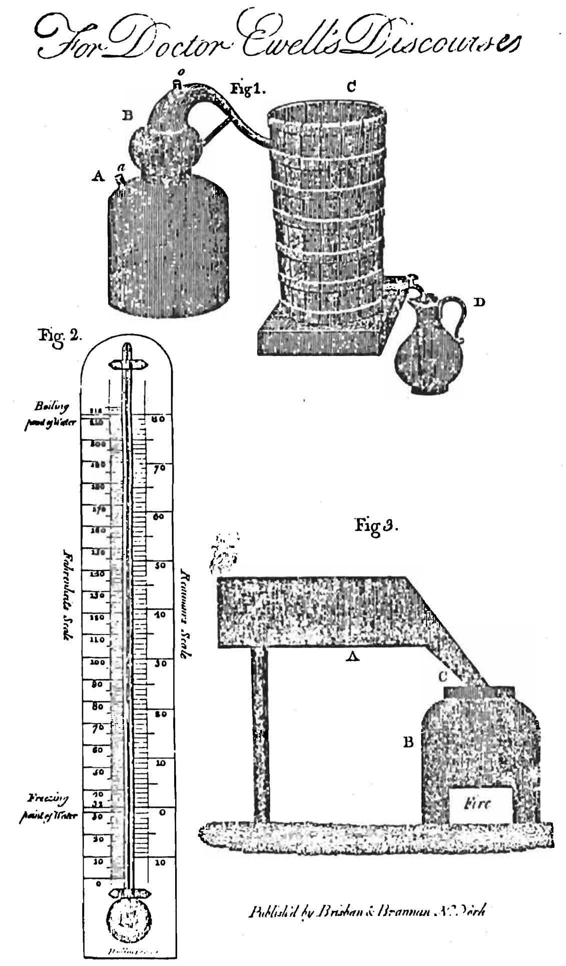
Thomas Ewell was born on 22 May 1785 on his family's estate near Dumfries, Virginia (12). Detailed information on his early life is not available but it is known that he studied medicine with Dr. George Graham of Dumfries and shortly thereafter with Dr. John Weems in Washington, D.C. His medical studies were pursued at the University of Pennsylvania, where he received his M.D. in 1805. Among his instructors at this institution was Dr. Benjamin Rush, one of the first teachers of chemistry in Colonial America.

Upon graduation, Ewell published his thesis, entitled *Notes on the Stomach and Secretion*, in which he carried out one of the early studies in digestive biochemistry. His research focused on the biological effects of gastric juice, emphasizing its dissolving ability and its potential medicinal value. He proposed that it might be possible to mix specific drugs, such as opium, in set doses with the gastric juice taken from a healthy animal, with the result that the drug would become more effective. Ewell designed experiments to find out what would happen if there was an accumulation of blood in the stomach. One of his major arguments was that colored bile associated with certain disease states was not formed in the liver, as was commonly believed, but was formed in other parts of the digestive system not directly associated with the liver. His thesis was noteworthy not only because it was one of the earliest to deal with this topic, but also for the original ideas he articulated.

Ewell accepted an appointment as a surgeon in the U.S. Navy on 2 November 1805 and in 1806 took charge of the Marine Guard at New York. From 1807 to 1813 he was attached to the Washington Navy Yard. During the latter part of his appointment he was actively involved in the setting up and the operation of a powder manufactory near Bladensburg, Maryland. After his resignation from the Navy, he remained in the area to take care of the powder mill, which did not become successful commercially, and to institute a private medical practice. He left Washington D.C. about 1815 to return to Philadelphia in order to attend lectures and to pursue his writing interests, returning again to the District of Columbia in 1819 to practice medicine. There he remained until he moved to his country estate, "Belleview", in Prince William County, Virginia. Subsequently he moved to Centerville, Virginia, which was his final residence.

Ewell's interests were focused largely on medical rather than chemical matters, but his connection with gunpowder research resulted in the development of several techniques designed to improve the efficiency and safety of gunpowder manufacturing. Three patents relating to these techniques were awarded to him (13). He is believed to be the first gunpowder manufacturer to use a wheel to incorporate the gunpowder ingredients. This method was in sharp contrast with the more dangerous stamp mills that were in use at the time in this country. His second technique involved the use of steam to bring about a liquid slush instead of handling a dry mass. This technique was not used again in the United States until a Colonel Rains reintroduced it during the Civil War. The third innovation was the creation of a new granulating machine of which nothing is known, since the patent records were destroyed by fire and the advertisements for the machine contain no specific details about either its design or operation.

Besides his chemistry text and his various articles in the *Medical Repository*, Ewell authored several other books. His book, *Letters to Ladies*, published in 1817, concerned basic medical advice for women and children. A compilation of his previous papers and addresses was published in 1819 as *Statement of Improvements in Medicine*. His *American Family Physician*, published in 1824, was a popular guide to medical treatments. He also edited the first American edition of David Hume's *Philosophical Essays on Morals, Literature and Politics*, and coauthored several reports of which the most significant was a report on the Naval Hospital System and a plan to establish a general hospital in the District of Columbia area.



A plate from Ewell's *Plain Discourses*

Ewell's brother, Dr. James Ewell, was a distinguished physician who also had an outstanding record of achievement. After his medical education and practice in Virginia, he moved to Savannah, Georgia, where he worked to introduce the practice of vaccination and wrote the first edition of *The Planter's and Mariner's Medical Companion*. This was sold extensively in the south and west and a total of ten editions were published. James later became a leading physician in the

Washington, D.C., area, and spent his final years in New Orleans.

In 1807 Ewell married Elizabeth Stoddert, the daughter of Benjamin Stoddert, first Secretary of the Navy. They had four daughters and five sons, two of whom - Benjamin Stoddert Ewell and Richard Stoddert Ewell - were distinguished Confederate officers. Thomas Ewell died on 11 May 1826 at the age of 41. Unfortunately, no portraits or other likenesses of him appear to have survived.

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4. T. Ewell, *Plain Discourses on the Laws or Properties of Matter*, Brisban and Brannan, New York, 1806, pp. 12-14.
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BOOK NOTES

A Science of Impurity: Water Analysis in Nineteenth Century Britain. Christopher Hamlin, University of California Press, Berkeley and Los Angeles, 1990. xiii + 342 pp. Cloth (Typeset). $45.00.

This is an extremely interesting case study of a little explored aspect of the rise of the professional chemist - the role of chemists - or, indeed, of scientists in general - as expert consultants on matters of public health. Beginning with the analysis of mineral waters in the 18th century and extending through the debates on the relative roles of bacteriology versus chemistry in water purification and management at the end of the 19th century, Hamlin gives a disturbing picture of chemists willing to assume the role of public expert, both for reasons of enhancing the public status of their profession and in order to financially supplement their often none too remunerative academic and industrial positions, while at the same time admitting within the chemical literature that the analytical procedures they employed in making their expert pronouncements were lacking a sound scientific basis.

The problems plaguing scientific water analysis were of two kinds. The first of these, and the only one which properly fell within the province of the chemist, was the problem of destructive versus nondestructive methods of analysis. Were the ingredients reported by the chemist actually present as such in the water or were they generated from other ingredients by the process of chemical analysis?

In modern terms, this reduces to the question of whether one is using chemical or physical methods of analysis. Classical chemical analysis, which was the only kind available for most of the 19th century, basically consists of synthesizing known compounds from unknown compounds and is decidedly destructive. Though it can be used to infer unambiguously the elemental composition of the unknown, inference of its molecular composition and structure requires additional, and often highly questionable, assumptions.

A very suggestive theoretical analysis of these problems had been given by Berthollet early in the 19th century, and the implications of hollet's theory for water analysis were clearly spelled out by the Scottish chemist, John Murray, in 1815. Nevertheless, many chemists concerned with water analysis continued to ignore these difficulties throughout the rest of the century. Writers on the history of analytical chemistry have frequently commented on the fact that an explicit theory of chemical analysis did not begin to develop until the last decade of the 19th century and nowhere is this lack of a guiding theory for the design and evaluation of empirical methods of analysis more apparent than in Hamlin's account of 19th century water analysis.

The second problem which plagued water analysis was whether the chemical ingredients the chemist was attempting to detect actually had the cause and effect relation to public health claimed by the medical profession. This question is really outside the province of the chemist, though this did not stop several of them from taking public stands on this issue.

Aside from a rather cumbersome method of recording the references and footnotes, this volume is highly recommended on all counts, especially to those interested in the history of chemical analysis, in the rise of the chemical profession, and in the larger question of the role of science in public policy decisions. *William B. Jensen, University of Cincinnati, Cincinnati, OH 45221.*

Aproximación a la evolución histórica de los métodos de adjuste de las ecuaciones químicas. Lluis Garrigós i Oltra, Instituto de Cultura Juan Gil-Albert, Alicante, 1990 (in Spanish). 110 pp. Paper (Typeset). $6.00.

This short monograph is basically an historical review of various methods that have been proposed for balancing chemical equations. As such, it falls somewhere between the history of science literature, on the one hand, and the educational literature, on the other. On the whole, it is probably of most relevance to chemists interested in chemical education, but may also be of interest to philosophers of science looking for an entrée into the meaning and ontological status of chemical equations.

Though the author cites a few late 18th and early 19th century textbook discussions (mostly from Spanish texts) of how to balance chemical equations, the vast majority of the monograph deals with the late 19th century literature found in Crookes' *Chemical News* and the 20th century literature found in both the *Journal of Chemical Education* and in *Chemistry Magazine*. Since this is a subject that has long interested the reviewer, he can verify that the author has done a thorough job of tracking down most of the pertinent references.

The author concludes that all of the methods are equally valid. While this is certainly true in the obvious sense that ultimately they all lead to the same result - namely a properly balanced equation - the reviewer would disagree that all of them are equally explicit in revealing the basic assumptions involved in the use of balanced equations. Ever since its introduction by James Bottemley in 1877, it has been known that the so-called algebraic method of balancing equations, also known as the "method of equations of balance", is the most fundamental available, since it is explicitly based on the twin principles of conservation of elements and conservation of charge in all chemical reactions. Not only does this approach allow one to balance the most difficult equations, it provides, in the form of a "degree of freedom" calculation, a check on whether pertinent information is missing in the equation and on whether one is actually dealing with a single chemical reaction or with the sum of several simultaneous reactions.

However, since the method requires the solution of a set of simultaneous algebraic equations (one for each element and one for the net charge), its lack of appeal in an introductory chemistry course is self-evident. In lieu of this rigorous approach, students are taught instead to balance equations by "inspection" and, when the equation is too complex to readily do this, they are given various rules for formally dissecting it into a set of simpler "half-reactions", each of which, when coupled with such artifical devices as oxidation state conventions and hypothetical electron transfers, is separately amendable to the inspection method. The balanced half-reactions are then added together to give the final overall balanced equation.

Granted that there are sound pedagogical reasons for avoiding the rigorous approach at the introductory level, the question remains as to why this subject is not reviewed again in a more sophisticated manner in introductory physical chemistry courses. As things now stand, chemical engineers are exposed to the algebraic approach but not professional chemists. One result of this educational hiatus has been the continued propagation of an embarrassing literature on "nonstoichiometric reactions" in the *Journal of Chemical Education*. Translation of this book into English would do much to alert American chemical educators to this flaw in our training.

Copies of the book can be ordered by writing to the Editor, Ins "Juan Gil Albert", Av. Estacion 6, 03005- Alicante, Spain. *William B. Jensen, University of Cincinnati, Cincinnati, OH 45221.*

The Japanese and Western Science. Masao Watanabe, University of Pennsylvania Press, Philadelphia, PA, 1990. xiv + 141 pp. Cloth (Typeset). $28.95.

This is an English translation, by O. T. Benfey of the Beckman Center for the History of Chemistry, of a German translation of the original Japanese text published in 1976. The book contains seven, largely independent, essays dealing with various aspects of late 19th and early 20th century contacts between Japan and Western science, mostly in the fields of biology and physics. The emphasis is on how the Western scientific concepts (and their early representatives) were subtly modified by their contact with traditional Japanese culture. The essays are straightforward accounts unmarred either by national chauvinism or the historiographic pretensions which abound in much of the recent literature in history of science. The book is amply illustrated with both photographs and line drawings, though some of the former are of rather poor quality.

Though chemistry is not discussed, the volume is recommended to those interested in the history of Oriental science and in the larger question of how science both reflects and impacts on the culture of which it is a part. Chemists may wish to read it in conjunction with the detailed account by Shilhara and McBee of the introduction of chemistry into Japan which appeared in *Chemical & Engineering News* in 1988 (Oct. 31, pp. 26-40).

Svante Arrhenius. Yu. I. Solovyov, Nauka Publishing, Moscow, 1990 (in Russian). 320 pp. Cloth (Typeset). NPG.

Directed at a general audience interested in the history of science, rather than just at physical chemists, this short biography of Arrhenius deals not only with his work on the ionic theory of dissociation and the temperature dependency of reaction rates, but with his later sorties into the fields of immunology and cosmology. The book is properly footnoted and contains a complete bibliography of Arrhenius' publications. It isn't apparent to what extent this volume derives from the earlier biography of Arrhenius by Solovyov and Figurovski published in 1959.

From Chuit & Naef to Firmenich. S.A. Roger Firmenich, Firmenich Incorporated, Geneva, 1990. 139 pp. Paper (Typeset). NPG.

This lavishly illustrated volume traces the history of this well-known Swiss-based perfume and flavor company from its founding by Philippe Chuit and Martin Naef in 1895 to its present status as an international operation employing more than 2000 persons in 18 different countries. The volume traces not only the administrative aspects of the company's history but its involvement in research and development, including its interactions with such famous chemists as Léopold Ruzicka and Max Stoll.

LETTERS

Lavoisier's Instruments

The apparatus and instruments used by Lavoisier are discussed by a number of authors in the Winter 1989 (No. 5) issue of the *Bulletin*. However, contrary to what is commonly believed, much of his extant equipment was known to exist well before the 20th century. The first modern notice of Lavoisier's apparatus is probably the publication of Truchot in 1879 ("Les Instruments de Lavoisier", *Ann. Chim. Phys.*, **1879**, *18*, 289-319). This paper provides an account, in somewhat embellished style, of a visit to the château of M. Étienne de Chazelles, a descendent of Madame Lavoisier, near Aigueperse, Puy-de-Dôme and, in addition, mentions other items then in the Conservatoire des Arts et Métiers. Truchot describes the balances and other pieces of equipment preserved by the family of Madame Lavoisier. The famous painting of Lavoisier and his wife by David is also mentioned as being viewed during the vist to the château.

Ronald K. Smeltzer, Princeton, New Jersey

AWARDS

The Dexter Award

The 1991 Dexter Award for outstanding accomplishment in the history of chemistry has been awarded to Dr. Owen Hannaway of Johns Hopkins University. The award, which consists of a cash prize of $2000 and an engraved plaque, was presented to Dr. Hannaway at the Fall National ACS Meeting in New York City.

Born in Scotland, Dr. Hannaway received his B.Sc. in chemistry from the University of Glasgow in 1961. This was followed by a Ph.D. in 1965 for a thesis on "Early University Courses in Chemistry" with particular emphasis on the 17th century. After one year as a postdoctoral fellow under Aaron Ihde at the University of Wisconsin, Dr. Hannaway went to Johns Hopkins in 1967 as an Assistant Professor in the History

Owen Hannaway

of Science Department. He became Professor of History of Science in 1977 and has since served several terms as chairman of the department.

Author of numerous articles and reviews, Dr. Hannaway is perhaps best known for his 1975 monograph, *The Chemists and the Word: The Didactic Origins of Chemistry*, which contrasts the 16th century texts of Oswald Croll and Andreas Libavius and their importance in the rise of modern chemical education.

The Division would at this time also like to solicit nominations for the 1992 Dexter award. Nominations should include a complete vita for the nominee, consisting of biographical data, educational background, awards and honors, publications, presentations and other services to the profession; a nominating letter summarizing the nominee's achievements in the field of the history of chemistry and citing unique contributions which merit a major award; and at least two seconding letters. Copies of no more than three publications may also be included, if available. All nominations should be sent in triplicate to Dr. James Traynham, Chairman of the Dexter Award Committee, Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803 by 1 January 1992. It should be emphasized that the award is international in scope and that nominations are welcomed from all quarters. Previous winners have included historians and chemists from Germany, France, Holland, Hungary, and Great Britain.

The Outstanding Paper Award

The 1990 Outstanding Paper Award has been given to Dr. Reynold E. Holmen of White Bear Lake, Minnesota for his paper, "Kasimir Fajans (1887-1975): The Man and his Work", which appeared in two parts in the Fall 1989 (No. 4, pp. 15-23) and Spring 1990 (No. 6, pp. 7-15) issues of the *Bulletin*, and the 1991 Outstanding Paper Award has been given to the late Denis Quane of East Texas University for his paper, "The Reception of Hydrogen Bonding by the Chemical Community: 1920-1937", which appeared in the Fall 1990 issue (No. 7, pp. 3-13).

The award, which consists of $100, a plaque, and $150 worth of books from Kluwer Academic Publishers, was presented to Dr. Holmen at the Fall National ACS Meeting in New York City. Dr. Quane's award was accepted on his behalf by his sister, Anna Deshamais. All papers published in the *Bulletin* are automatically considered for the award for up to three years after the date of their publication.

The Edelstein Fellowship

The 1991-1992 Edelstein Fellowship in the History of Chemical Sciences and Technology has been awarded to Dr. Peter J. T. Morris of Britain's Open University. Dr. Morris will divide his fellowship year between the Beckman Center for the History of Chemistry in Philadelphia and the Edelstein Center for History and Philosophy of Science, Technology and Medicine in Jerusalem.

The Partington Prize

The 1990 Partington Prize has been awarded to Marco Beretta of Uppsala University for his essay "The History of Chemistry in the Eighteenth Century". The prize of £100 is awarded every three years by The Society for the History of Alchemy and Chemistry for the best original unpublished essay on history of chemistry by a scholar under the age of 30.

EVENTS OF INTEREST

* The Oesper Museum of Chemical Apparatus has received donations of several artifacts related to recent articles in the *Bulletin*. William D. Williams of Harding University has sent in a sodium basket similar to the one discussed in the article "Reinventing the Hofmann Sodium Spoon", which appeared in the Fall 1990 issue (pp. 38-39). The Chemistry Department of the College of Saint Thomas in Saint Paul, Minnesota, has donated an example of one of the first Becker chainomatic balances as discussed by John Stock in the Winter 1990 issue (pp. 12-15). The balance carries an acquision date of 1920 and the original 1916 patent number. Alex and Hortense Berman of Cincinnati have donated an original lithograph of the Honoré Daumier caricature of the French chemist, Jean-Baptiste Dumas, which was used on the cover of the same issue. The caricature originally appeared in the 4 March 1850 issue of the journal *Le Charivari* and was intended to satirize Dumas' performance as Minister of Agriculture. Dr. Berman has also provided a translation of the original caption:

> New prodigy of chemistry: Dumas has managed to produce a ministerial portfolio from his retort. Since coming to the ministry, the chemist Dumas has always been careful to avoid the podium, on the pretext that he is always occupied in analyzing the speeches of other orators.

* Several activities of the Division have received publicity in recent issues of *Chemical & Engineering News*. The paper, "A Reevaluation of Dalton's Data on Combining Proportions: Were his Results Fraudulent?", given by Melvyn C. Usselman and K. D. Watson of the University of Western Ontario at the Spring 1991 National ACS Meeting in Atlanta, was highlighted in the 6 May issue (pp. 43-44), and the Faraday Symposium held at the same meeting, and organized by Derek Davenport of Purdue University, was the cover article for the 23 September issue. The papers given at this syposium will appear as a special Winter issue of the *Bulletin* which will be published in early March.

* The International Academic Conference on Chinese Scientific and Technical History will be held in Hangzhou, Zhejiang Province of the People's Republic of China on 25-30 August 1992. For further information contact the Secretariat of the International Academic Conference on Chinese Scientific and Technical History, 211 Yan'an Road, 310006 Hangzhou, People's Republic of China or contact Shi Nam, Yao YaQin, Tel. 556105, 555006, Telex. Hangzhou 0571-551101.

* An international symposium in celebration of the centenary of the death of August Wilhelm Hofmann, organized by the Gesellschaft Deutscher Chemiker, The Royal Society of Chemistry, and Humboldt Universität, will be held in Berlin on 5-6 May 1992. Speakers will include W. H. Brock, L. Burchardt, W. Hornix, J. A. Johnson, O. P. Krätz, M. Rasch, C. A. Russell, and H. W. Schütt. For further details contact Gesellschaft Deutscher Chemiker, Abt. Tagungen, Postfach 900440, D-6000 Frankfurt am Main, Germany, Phone: (+69) 7919-360, Fax: (+69) 7917-475.

* The 19th International Congress of History of Science will take place in Zaragoza on 22-29 August 1993. For details contact Professor Mariano Hormigón, Faculdad de Ciencas, Ciudad Universitaria, E-50009, Zaragoza, Spain.

* A European colloquium to commemorate the bicentenary of Lavoisier's death, organized by the Académie des Sciences, will be held in Paris on 3-6 May 1994. For further details contact Madame Michèle Goupil, Secrétaire du Comité Bicentenaire Lavoisier, Académie des Sciences, 23 Quai Conti, 75006 Paris, France.

* Travel grants are available from the Beckman Center for the History of Chemistry to enable interested individuals to visit Philadelphia to make use of the Othmer Library, the Edgar Fahs Smith Collection, and other associated facilities. The grants, which may be used for travel, subsistence, and copying costs, will not normally exceed $500. Applications should include a vita, a one-paragraph statement on the research proposed, a budget, and the addresses and telephone numbers of two references. Deadlines are 1 February for grants covering the period April-June, 1 May for July-September, 1 August for the period October-December, and 1 November for the period January-March. Send applications to Lisa Kazanjian, Beckman Center for the History of Chemistry, 3401 Walnut Street, Philadelphia, PA 19104-6228, (215) 898-4896.

* The Oesper Collection in the History of Chemistry of the University of Cincinnati is looking for donations of old chemistry texts, photographs, prints, molecular models, and chemical apparatus to add to its collections. Interested parties should contact Dr. William B. Jensen, Department of Chemistry, ML 172, University of Cincinnati, Cincinnati, OH 45221.

FUTURE MEETINGS

San Francisco .... 5-10 April 1992

Five copies of 150-word abstract (original on ACS Abstract Form) by 1 December 1991. Title of paper by 1 November 1991.

* *General Papers.* Contact J. L. Sturchio, Corporate Archives, Merck & Co., Inc., P.O. Box 2000, Rahway, NJ 07065-0900, (908) 594-3981, FAX (908) 594-3977 or M. D. Saltzman, Department of Chemistry, Providence College, Providence, RI 02918, (401) 865-2298.

* *Bay Area Biotechnology: History As It Happens.* Contact H. Lowood, History of Science & Technologies Collections, Stanford University Libraries, Stanford University, Stanford, CA 94066, (415) 723-4602 or J. L. Sturchio, Corporate Archives, Merck & Co., Inc., P.O. Box 2000, Rahway, NJ 07065-0900, (908) 594-3981, FAX (908) 594-3977.

* *The Role of Chemistry and Materials in the Rise of Silicon Valley.* Contact H. Lowood, History of Science & Technologies Collections, Stanford University Libraries, Stanford University, Stanford, CA 94066, (415) 723-4602 or J. L. Sturchio, Corporate Archives, Merck & Co., Inc., P.O. Box 2000, Rahway, NJ 07065-0900, (908) 594-3981, FAX (908) 594-3977.

* *Chemical Genealogy.* Contact P. R. Jones, Department of Chemistry, University of New Hampshire, Durham, NH 03824, (603) 862-1550.

* *The Role of Chemistry in Science Fiction.* Contact J. H. Stocker, Department of Chemistry, University of New Orleans, New Orleans, LA 70148, (504) 286-6852.

Geneva .... 22-24 April 1992

* *100th Anniversary of the Geneva Conference.* Organized by J. G. Traynham, Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803, (504) 388-3459.

Washington DC .... 23-28 August 1992

Five copies of 150-word abstract (original on ACS Abstract Form) by 15 April 1992. Title of paper by 1 April 1992.

* *General Papers.* Contact M. D. Saltzman (see address above).

Denver .... 28 March - 2 April 1993

Five copies of 150-word abstract (original on ACS Abstract Form) by 1 December 1992. Title of paper by 1 November 1992.

* *General Papers.* Contact M. D. Saltzman (see address above).

Chicago .... 22-27 August 1993

Five copies of 150-word abstract (original on ACS Abstract Form) by 15 April 1993. Title of paper by 1 April 1993.

* *General Papers.* Contact M. D. Saltzman (see address above).

* *C. K. Ingold , 1893-1970. Master and Mandarin of Physical Organic Chemistry.* Contact M. D. Saltzman, Department of Chemistry, Providence College, Providence, RI 02918, (401) 865-2298, or Derek Davenport, Department of Chemistry, Purdue University, West Lafayette, IN 47907, (317) 494-5465.

Tentative Future Symposia

(Please contact J. L. Sturchio if you are interested in organizing or participating in the following.)

- *Chemistry and Communications*
- *History of Chemical Processes in Industry*
- *Case Histories of Drug Discovery and Development*

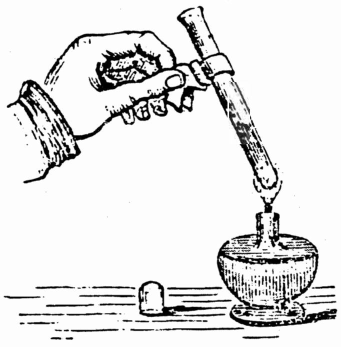
Note: The cosponsored symposia indicated with parentheses will have their primary sponsorships by the divisions so named and the programs will appear under their respective divisional headings.

PARTING SHOTS

The Stoddard Test Tube Clamp

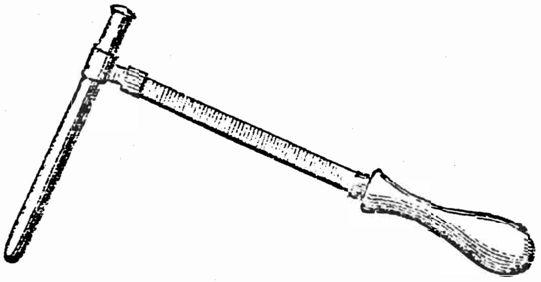
William D. Williams, Harding University

The ubiquitous spring wire test tube holder is such a simple, logical, convenient device that we tend to assume that it has been in use forever. Surprisingly, it was invented about 1886 by an American chemist, John T. Stoddard. Although chemical supply catalogs from 1893 to the present day have listed this item as the "Stoddard test tube clamp", Stoddard himself remains relatively unknown.



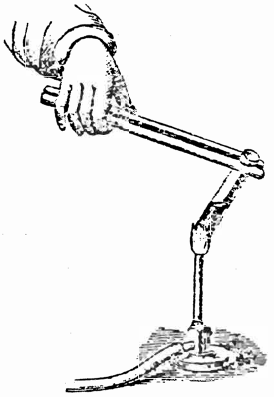
A paper twist test tube clamp, circa 1850 (1)

Prior to 1890 the most often used test tube clamp was a strip of heavy paper twisted around the test tube (1). Campbell Morfit, in his 1857 encyclopedic *Chemical and Pharmaceutical Manipulations*, described a sophisticated "spring holder, consisting of a wooden handle affixed to two flat pieces of sheet brass, indented at their ends so as to form a round catch, and tightened or loosened by a slide" (2).



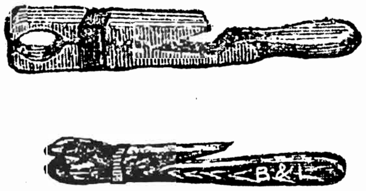
Morfit's metal slide clamp, circa 1857 (2)

A prominent text of 1873 described "wooden nippers, made with two bits of wood about a foot long, hinged together at the back and at once connected and kept apart by a sliding steel or brass spring, somewhat like those used on certain pruning shears" (3).



A wooden nippers clamp, circa 1873 (3)

Chemical supply catalogs of the 1890s and early 1900s offered a test tube clamp made of two notched pieces of wood held together by a heavy rubber band (4).

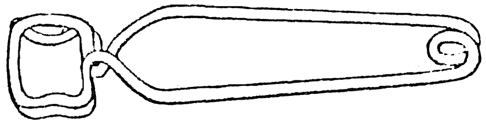


The rubber band clamp, circa 1890 (4)

John T. Stoddard found this last mentioned clamp objectionable and in 1890 published a paper describing his "New Test Tube Holder" (5):

> The annoyance experienced in using the common wooden test-tube holder led me some years ago to attempt to devise a holder which should serve its purpose more perfectly. The wooden holder is clumsy, its rubber band rots and is liable to give way at awkward moments, the peg becomes unglued and drops out, and even in its best estate it holds securely only medium-sized test-tubes ... The new holder has been in use in my laboratory for four years now, and has given such good satisfaction that I venture to call attention to it in a form recently somewhat improved. It is made of brass wire, and opens by pressure on the straight sides of the handle; its jaws open to the width of 5 cm and it holds firmly any tube from 5 mm up. I have recently had a larger size made of stiffer wire for the purpose of holding flasks, &c. It proves very convenient as a holder of wash-bottles when one is washing with boiling water, and also for holding beakers when decanting hot solutions. Both sizes are furnished by the Victor Manufacturing Co., Northampton, Mass.

Stoddard's article included a drawing of the clamp that is almost identical to those in current apparatus catalogs.



Stoddard's original wire test tube clamp, circa 1890 (5).

John Tappen Stoddard (1852-1919) graduated from Amherst in 1874 and received a Ph.D. under Hans Hübner at Göttingen, Germany in 1877. Joining the faculty of Smith College, Northampton, Massachusetts in 1878, he served 41 years as professor of chemistry and physics. A new chemistry building he helped design in 1898 was named Stoddard Hall after his death (6). Primarily an educator rather than a researcher, he encouraged undergraduate research at Smith and wrote chemistry texts that were widely used through several editions, including a volume on qualitative analysis (7), two general chemistry texts (8, 9), a laboratory manual for general chemistry (10) and an organic text (11). A slightly different aspect of his personality is revealed in his book, *The Science of Billiards with Practical Applications*, which he published in 1913 (16).

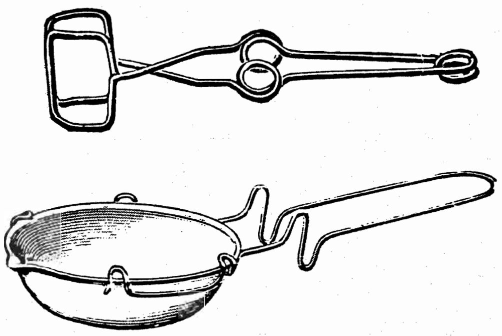
A search of early American chemical supply catalogs reveals that Stoddard's clamp was quickly accepted. The 1893 catalog of Emil Greiner listed "Clamps, of brass, Stoddard's form, in two sizes, the smaller suitable for all sizes of test tubes; the larger, of stiffer wire, for holding flasks, wash-bottles with boiling water, or beakers, when decanting solutions. Small size, 20 cents each; Large size, $0.25" (12). This same catalog also offered the wooden-rubber band model for 15 cents and the wooden handle-metal with slide catch model for 40 cents. The 1906 Arthur H. Thomas catalog listed the wooden-rubber band model for 15 cents and "Stoddard's Test Tube Clamp" for 15 and 20 cents in brass wire and for 10 and 15 cents in "nickeled" wire (13). The 1914 E. H. Sargent catalog offered "Stoddard's Clamps for Test Tubes, of spring brass" for 10 cents and a wood clamp of "improved construction with wire spring' for 10 cents (14). The latter was the clothes-pin type that, despite its antiquated look, is still available in some 1991 catalogs.

John Tappen Stoddard (15)

A clothes-pin clamp, circa 1914 (14)

Although Stoddard's original design is still available in all current apparatus catalogs, some suppliers no longer use his name in the listing. The clamp is attributed to Stoddard in the 1991 Sargent-Welch catalog, the 1990 catalog of Carolina Biological Supply Co. and the 1990 Cenco catalog. The 1988 Arthur H. Thomas catalog identifies this model as "Test tube holder, Thomas", but offers a modified model as "Stoddard-Thomas." Recent Fisher Scientific catalogs do not use the name Stoddard, but their 1972 and earlier catalogs identified it as "Clamp, Stoddard." Some suppliers also list a second

Stoddard model with "finger grips" and a "Stoddard Dish Clamp, for holding and manipulating evaporating dishes".



Modern versions of Stoddard's wire clamps

References and Notes

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2. C. Morfit and C. Morfit, *Chemical and Pharmaceutical Manipulations* ..., Lindsay and Blakiston, Philadelphia, 1857, p. 446.

3. W. Nichols, *An Elementary Manual of Chemistry*, Ivison, Blakeman, Taylor and Company, New York, 1873, p. 2 and xxx.

4. *Illustrated and Priced Catalogue of Chemical Apparatus*, Emil Greiner, New York, 1893, p. 85; *Laboratory Apparatus ... Catalogue F*, Arthur H. Thomas Company, Philadelphia, 1906, p. 126.

5. J. Stoddard, "Notes from the Laboratory of Smith College," *Journal of Analytical Chemistry*, **1890**, *4*, 34; Reprinted in *Chemical News (London)*, **1890**, *61*, 223-224.

6. See biographies in W. Miles, *American Chemists and Chemical Engineers*, American Chemical Society, Washington, 1976, pp. 460-461 and *Dictionary of American Biography*, Vol. 18, Charles Scribner's Sons, New York, 1936, p. 56.

7. J. Stoddard, *Outline of Qualitative Analysis for Beginners*, Northampton, MA, 1883.

8. J. Stoddard, *Outline of Lecture Notes on General Chemistry*, Gazette Publishing, Northampton, MA, 1884 and 1885.

9. J. Stoddard, *Quantitative Experiments in General Chemistry*, Longmans, Green & Co., London, 1908.

10. J. Stoddard, *Introduction to General Chemistry*, Macmillan, New York, NY, 1910.

11. J. Stoddard, *Introduction to Organic Chemistry*, Blakiston, Philadelphia, PA, 1914.

12. *Illustrated and Priced Catalogue of Chemical Apparatus*, Emil Greiner, New York, 1893, p. 86.

13. *Laboratory Apparatus ... Catalogue F*, Arthur H. Thomas Company, Philadelphia, 1906, p. 126.

14. *Scientific Laboratory Apparatus*, E. H. Sargent & Company, Chicago, 1914, p. 90.

15. Courtesy of Smith College Archives.

16. J. Stoddard, *The Science of Billiards with Practical Applications*, Butterfield, Boston, MA, 1913.

Dr. William D. Williams is well known to readers of the Bulletin for his articles on early American chemistry texts which appear regularly in the Old Chemistries column. He is Professor of Chemistry at Harding University, Searcy, AK 72143.

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