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Division of the History of Chemistry of the American Chemical Society

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Jean-Baptiste Dumas and Chemical Romanticism

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The Cover...

This issue shows a 19th century caricature of the French chemist, Jean-Baptiste Dumas (1800-1884) by the famous French political and social caricaturist and artist, Honoré Daumier. Dumas is the subject of Ben Chastain's article in this issue, which highlights some curious parallels between Dumas' life and career and that of the French writer and dramatist, Victor Hugo.

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

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PERSPECTIVES LECTURE

History of Chemistry and the Education of Teachers

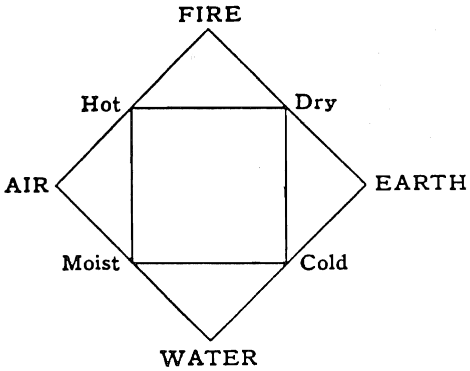
Aaron J. Ihde, University of Wisconsin - Madison

Early in my teaching career I became convinced that history has value in causing the student to look at chemistry in a realistic fashion. But, like classroom demonstrations, history should fulfill a teaching objective and not be used merely as entertainment. Further, history is made by human beings and lends a human interest which is lacking when only the facts of chemistry are expounded (1).

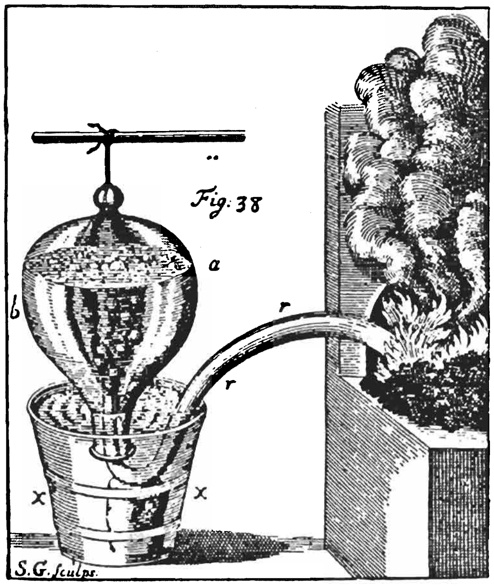
Merely telling students that Priestley discovered oxygen is a historical fact which frequently leads to some yawns and even the query, "Do we have to know that on the exam?" If we introduce Priestley at all, let's make him meaningful. Why did Priestley, a minister, carry out an experiment which produced oxygen? Because he wished to better understand the design of the Creator. Are you aware that many of the names in 17th and 18th century science were theologians and nearly all scientists of the day were deeply devout? That point is worth further discussion.

Why was Priestley carrying out an experiment which produced oxygen? Because he was, like many of his contemporaries, a pneumatic chemist. Why were there so many pneumatic chemists at that moment? Because Stephen Hales, another theologian, had invented the pneumatic trough a half century earlier (2). For the first time in human history it was possible to isolate airs by decomposition of chemical substances and collect the resulting air comparatively free of contaminants. Hales developed the apparatus because he was curious to learn how much air was trapped in various solids in non-aerial form. He measured the volume of air which could be driven out of various chemicals, rocks, seeds, and plants by heating (3).

Hales' objective was wrong. Rather than asking "How much air?" he should have been asking, "What kind of air?" At that date the quantity of air obtained was of little significance but the nature of the air was important. Though at the time he failed to suspect that there are many kinds of airs, or more properly, gases, his efforts were not totally lost. He introduced a new tool into the scientific world which allowed others to avidly pursue the study of new gases. Scientific progress is accompanied by a vast amount of stumbling, some of it fruitful for the wrong reason.



The four elements of the Greeks

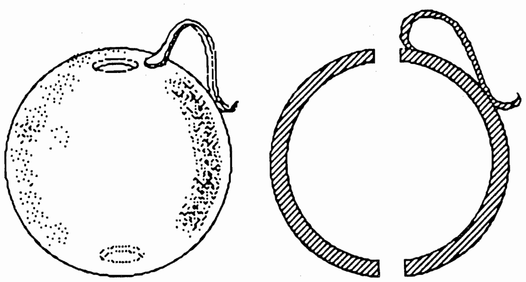


Stephen Hale's pneumatic trough

The Priestley-Hales incident illustrates some important points. An experiment should have an objective but the experiment need not achieve that objective. If it uncovers some useful knowledge, it has not been a failure. Hales produced a useful piece of apparatus which soon advanced the chemical study of gases and their sources. Priestley discovered oxygen with a modification of the apparatus. However, he did not call his gas oxygen, but named it dephlogisticated air. Why? Because he was a creature of his time, not because he was stupid. But that is another story.

Stephen Hales was also a philosophical product of his time. A gas was simply air, a substance that had been considered elemental since antiquity. The Greek philosophers believed there were only four elements: earth, air, fire, and water. However, the four elements were not considered truly elementary since they were derived from a more primitive matter which had become elementary following the acquisition of two primary qualities: hot or cold, and wet or dry. The relationship was portrayed for many centuries in the form of a square of qualities within a square of elements.

Earth and water were easily identified and fire was a phenomenon easily recognized by its effects. What about air? The Greeks had demonstrated its existence soon after inventing the *clepsydra* as a device for carrying water or measuring



A Greek clepsydra

time. This was a glass or ceramic globe with a handle and two small holes, one at the top, the other at the bottom. When plunged into a pool of water, it filled with water through the bottom hole. If one then placed a thumb over the top hole, the clepsydra could be carried to the kitchen without loss of water through the bottom hole. Then, removal of the thumb over the top hole permitted the water to flow into other vessels. On the other hand, if the thumb were placed over the top hole before plunging the device into the water, no water entered the bottom hole and the globe failed to fill because it was already full of air, a substance which occupied space even though invisible.

Thus, centuries later Hales still looked upon all gases as air and it was his successors, particularly Priestley, who recognized that there are more than a dozen different airs which could be prepared and collected in the pneumatic trough.

The four-element hypothesis remained popular through the Middle Ages and actually stimulated the pursuit of alchemy for more than a millennium in Greece, Egypt, Arabia, China and Europe. The notion that the elements could be transformed into one another by abstracting and introducing qualities led to the notion that base metals, such as lead, tin, or iron, could be transmuted into silver and gold by alteration of certain characteristics such as color. It was only after centuries of failure to transmute or perfect base metals into gold that chemical philosophers began to lose interest in transmutation and sought to examine matter more thoughtfully.

In truth, the 16th and 17th centuries were a rich period for progress in understanding the heavens, the atmosphere, the earth and, more slowly, the nature of living organisms. The age of the great navigations led to knowledge of new flora and fauna while creating problems such as determining one's location on the earth's surface. It was learned that the heavens were not perfect and that the earth revolved about the sun and not vice versa. Ancient beliefs began to be questioned and this challenge was stimulated by the development of new tools and the improvement of old ones, such as the balance, the still, and the compass. All these devices had previously had a vastly greater role in commerce than in natural philosophy. Concern with instruments added, during this period, the mechanical clock, the telescope, the barometer, the air pump, the thermometer, and a primitive microscope.

With this new armament of tools, scientific phenomena could be investigated more effectively. The opportunity to gain understanding of old mysteries attracted new investigators into the field. The universe was a vast system amenable to investigation and even measurement.

Although physics and astronomy responded quickly to investigation during the Enlightenment, chemistry revealed its secrets more slowly. This is not surprising since chemistry is a subtle science not responsive to traditional methods of human observation. In part, the tardiness of chemistry is attributable to seeking understanding of the more complex properties of matter by experimenting with solids and liquids, while ignoring gases.

The emergence of pneumatic studies channeled chemical investigation in a fruitful direction since the properties of gases are more amenable to investigation than those of the other two states of matter. Lavoisier's insight that common air is not an element rich in hotness and wetness but is a mixture of two unique gases, initially labelled dephlogisticated air and noxious air, was an important step in turning chemistry into a direction for viable studies and improved understanding. He soon renamed these gases oxygen (acid former) and azote (without life). It was Chaptal who suggested "nitrogen" for the latter, since it is a component of nitre, and that name has had general acceptance (4).

Lavoisier went on to clarify the nature of combustion and calcination (burning without flame). Recent studies, particularly by Robert Siegfried in America and William Smeaton in England, have shown that Lavoisier, starting from the conventional wisdom of the phlogistonists, argued that, upon heating:

nonmetal → acid + phlogiston

metal → calx + phlogiston

Siegfried further suggests that Lavoisier, having recognized that phlogiston could be thought of as negative oxygen, then reformulated these reactions as:

nonmetal → acid + negative oxygen

metal → calx + negative oxygen

which, upon rearranging algebraically, gave our currently accepted versions:

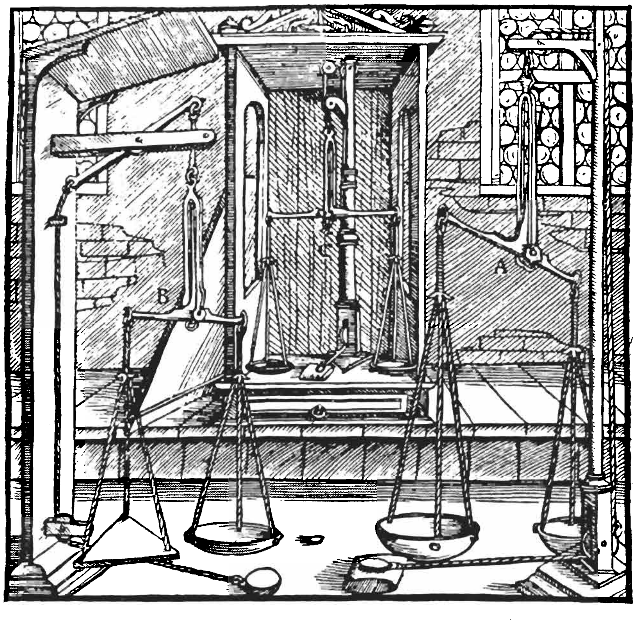
nonmetal + oxygen → acid

metal + oxygen → calx

Thus Lavoisier considered Priestley's dephlogisticated air as the principle of acidity. Actually, he dramatized the phenomenon as a correction of a fallacious concept of combustion and calcination and spoke of his version as the "Anti-Phlogistic Theory". In truth, Siegfried has revealed that, while the phlogiston theory had been around for more than a century, it was used in a multitude of ways but was never highly regarded among leading scientific investigators. Lavoisier dramatized a generally known concept as something his investigations could overthrow (5).

Lavoisier's explanation of combustion began to attract adherents by 1785 and picked up additional disciples after the publication in 1787 of the *Méthode de nomenclature chimique*, which he coauthored in collaboration with Guyton de Morveau, Berthollet, and Fourcroy, and after the publication of his own *Traité élémentaire de chimie* in 1789. Although the phlogiston theory retained a few defenders, such as Priestley, the new chemistry quickly gained a strong following, despite some obvious flaws in Lavoisier's total system.

The book on nomenclature was an impressive treatise which superseded the unsystematic nomenclature of the past which had named chemicals after persons, industrial associations, appearance, color, taste, odor, place of origin, physiological effects, or other historical or chance observations. The four authors argued that names should be based on chemical composition, utilizing as the elemental basis a list of simple substances, soon to be called elements. Lavoisier's input into the nomenclature reform is clearly secondary to that of Guyton de Morveau, who had been publishing such arguments since 1780. Berthollet was apparently included as an author on the basis of his seniority and immense reputation; he appears to have contributed little if anything to the system. Likewise, though Fourcroy, the youngest of the authors, played an important role later in his position as a chemistry teacher, his early contributions were, at best, minimal.



Assaying balances from Agricola's *De re metallica* of 1556

The major success of Lavoisier's work was in revealing that chemical reactions have a quantitative basis. They can be checked by the chemical balance, just as a business transaction can be checked by the balance sheet, and Lavoisier was professionally a businessman. In a chemical reaction the masses of the reactants must be accounted for in the masses of the products.

Lavoisier's concept of oxygen as the acid former was questioned by Berthollet almost from the beginning and was demolished early in the next century by Davy, who established that marine acid (i.e., HCl) lacked oxygen. Other studies soon undermined Lavoisier's contention that oxygen was the sole agent of combustion or oxidation by showing that oxidation processes can be associated with a variety of oxidizing agents, many of which, like the halogens, contain no oxygen. In a similar fashion, Lavoisier's concept of the element caloric as a heat substance would give way to the concept of heat energy a half century later.

Like elements, atoms had been discussed since antiquity. Leucippus and his pupil Democritus philosophized about a particulate world at the time of Socrates in 5th century B.C. Athens. We have no original sources from either Leucippus or Democritus. What we know about ancient atomism is found in the writings of its critics. The theory was expanded somewhat later by the philosopher Epicurus, known primarily for his suggestion that life should be enjoyed. Our best source of what the atomists believed is found in the (1st century B.C.) Roman poet Lucretius' long poem *De rerum natura* (Concerning the Nature of Things) (6).

Ancient atomism never really caught on, in part because Epicurean philosophy became suspect by Christian theologians, but more particularly because it was a speculative philosophy which to many minds was less persuasive than the competing view of matter as a continuous plenum (a full universe). After all, an atomic system required a void in which the atoms could move.

Thus, the atomic philosophy of matter was largely rejected from late antiquity until well into the Renaissance. Following the work of Torricelli, Pascal, and Boyle, which demonstrated the reality of a vacuum, atomism started to make a reappearance, but more in the form of physical molecules, generally called particles or corpuscles, than in the form of indivisible chemical atoms.

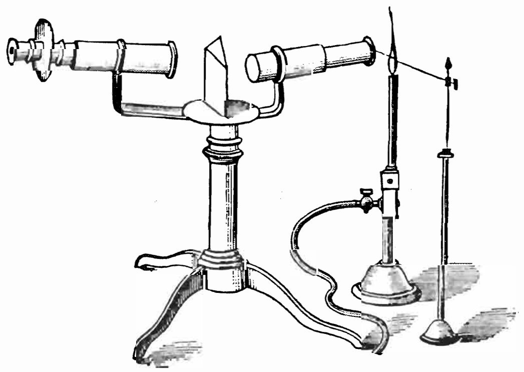
It was primarily John Dalton, after 1800, who recognized that atoms might be useful to chemists in connection with the post-Lavoisierian concept of elemental (simple) substances. While Dalton recognized that atoms had weight and that combining weights might reveal atomic weights, he was unable to produce a reliable table of atomic weights, partly because he was not a good analyst, but primarily because he lacked the insight to deduce correct formulas. His Swedish contemporary, Berzelius, was a superb analyst whose insight into certain chemical relationships led him to satisfactory formulas and hence to satisfactory atomic weights (7).

Through the investigations of Dalton, Berzelius, Avogadro, Dumas, and Cannizzaro there was a general acceptance of atoms of elements, and molecules of compounds and elements by 1870. The introduction of the periodic classification of the elements by Mendeleev was a strong factor leading to acceptance of elements, atomic weights, and family relationships among elements.

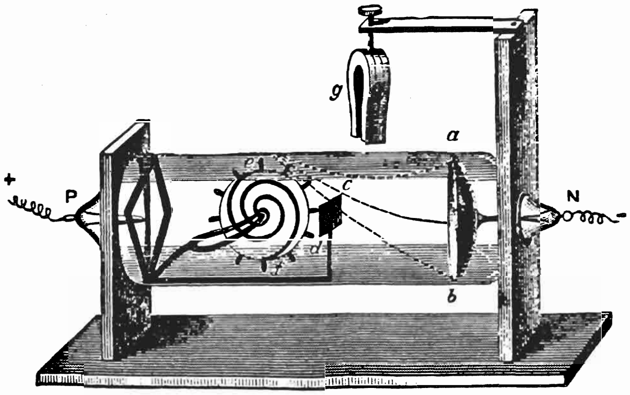
New discoveries, however, created new problems just as elements and atoms were being accepted. The introduction of the spectroscope by Bunsen and Kirchhoff in 1859 revealed that elements emitted and absorbed light under proper circumstances, and that each element emitted and absorbed light of very specific wave lengths. The spectroscope quickly led to the discovery of rubidium and cesium by Bunsen and Kirchhoff. William Crookes, when examining the spectrum of selenium, observed an anomalous green line which proved to be due to an impurity and led to the discovery of thallium. Others quickly uncovered several additional, new elements and, after that time, the spectroscope figured in the discovery or verification of almost all new elements. In astronomy the spectroscope soon provided information about the composition of stars and star systems, and the speed of their radial motion. Thus the creation of the physicist, the spectroscope, profoundly influenced the research of both chemists and astronomers (8).

The spectroscope quickly raised puzzling questions about atoms of elements. Johann Balmer found in 1884 that the wave lengths of the spectral lines of hydrogen formed a convergent series based on a simple mathematical formula. In the next several years he published similar results for the spectra of helium and lithium. The origin of such lines raised questions about whether the atom was truly a small homogeneous particle.

A second physical phenomenon raised further questions about the indivisible atom. About 1850 it was recognized that if two electrodes were placed in the closed ends of a glass tube and the air then evacuated, a current began to flow between the electrodes and, at a high degree of evacuation, a purple glow appeared. When a different gas was substituted in the evacuated tube, the flow took on a color characteristic of the specific gas. This phenomenon led, during a 40-year period of intensive research with different gases and with tubes of varying design, to a series of discoveries of sub-atomic phenomena which, by 1900, included positive rays, electrons, and X-rays.



A 19th century spectroscope



A 19th century Geissler tube designed by Crookes

In 1896 Antoine Henri Becquerel, while studying the fluorescence of various salts on exposure to X-rays, found that uranium salts sensitize a photographic plate long after they stop fluorescing. He quickly established the fact that uranium-containing materials are constantly undergoing a form of decay in which radiation, presumably X-rays, are emitted. It was soon established that the radiation had no connection with fluorescence and was a property of uranium itself.

At this point Marie Curie undertook a study to learn if radioactivity was present in other elements. She soon established thorium to be radioactive. Upon testing the mineral pitchblende (80% U_3O_8), she found the ionizing power to be several times that of pure uranium. She suspected the presence of another radioactive element and, with the help of her husband Pierre, set out to isolate it. By July 1898 they reported the presence of a new element which she named polonium, after Poland, her native homeland.

Since there was still very active radiation in the barium fraction, they also set out to isolate it. By December they had a concentrate which glowed in the dark and enabled them to announce the presence of a second new element, radium. Their material was still very impure and the next four years were spent in preparing a pure sample of radium chloride. From several tons of pitchblende residues from which the uranium had been commercially separated for glassmaking, they obtained 0.1 gram of radium chloride showing no spectroscopic evidence of contamination with barium.

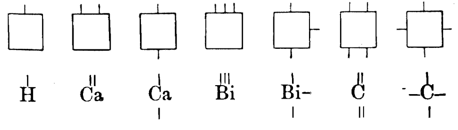
In the meantime, Becquerel discovered that a part of the radiation was deflected by a magnet in the same direction as cathode rays and was composed of electrons. About the same time, Ernest Rutherford learned that the radiation contained a very penetrating fraction, which he named *beta*, and an easily absorbed fraction, which he named *alpha*. He and his associates ultimately established that alpha radiation was made up of doubly positive helium ions, whereas *beta* radiation had already been identified as a beam of electrons. A third form of radiation, even more penetrating than the electrons, was named *gamma*. It was shown to be a form of short wave-length X-ray.

In looking at the state of atomism between 1860 and 1910, one observes the transformation of the atom from a small indivisible particle to an atom of parts. During the same period, chemists had been seeking an explanation of the nature of chemical combination. What was there about atoms that led to their combination to form molecules? Hooks and eyes were even suggested. Why did some compounds conduct electricity while undergoing decomposition while others did not decompose?

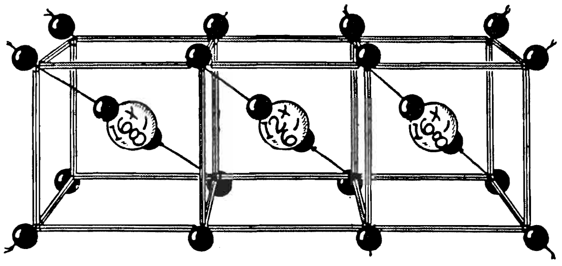
The concept of a complex atom with parts that can be shared with other atoms, or even transferred, began to be postulated before World War I and was expanded upon shortly thereafter. Somewhat naive atomic structures introduced by G. N. Lewis and Irving Langmuir provided an image of ionic and covalent combination which was widely adopted in teaching and research, despite their use of a static atomic model which clearly failed to represent dynamic reality.

In conclusion, I believe that history of chemistry has a place in the armament of chemistry teachers at all levels, but particularly at the introductory level. It humanizes the subject by making it a part of the human enterprise rather than leaving it as an abstract search for the understanding of chemical change. The discipline has had a profound impact on virtually every human enterprise, starting with agriculture and health and passing on to the extraction, processing, and production of raw materials for industry and finished products for the consumer (9).

Ultimately, the use of history reveals to the student that chemical knowledge is never static. New facts are being uncovered continually which must be tested against current theory. Frequently new facts create a strain upon contemporary interpretations of the existing facts and in time there may come a rejection of existing explanations in favor of more persuasive ones. More frequently, new facts cause a modification of existing explanations.



A late 19th century view of atomic combination in terms of hooks and eyes



A 3-D model of a Lewis-Langmuir cubical atom representation of carbon dioxide

As noted above, the word element has evolved from a fundamental something resulting from the presence of a pair of qualities into a set of 100-plus simple substances whose properties are determined by the number of protons and electrons (with a variable number of neutrons associated with each of the elements). However, we are now aware that the three components of atoms, when they collide at high velocities, are shattered into still smaller particles. Should we abandon our elements in favor of these fragments? I think not, at least not until the high energy physicists show us that their mesons and quarks are truly of fundamental relevance to chemists in explaining the nature of chemical change.

Natural philosophers have been learning over a period of more than 2,000 years that the interpretation of experimental observations is subject to change following the acquisition of new knowledge. Our students are entitled to become aware that, while there are no final answers at the level of present knowledge, there are still useful answers which are worth understanding. They should also be aware that even the most persuasive items of knowledge are subject to change in the future. The expansion of chemical knowledge in the past three centuries has been very impressive, particularly in the past century, but we must make students realize that there will continue to be changes in the next century as well. They must be prepared to understand that our present knowledge is still subject to change. By understanding change in the past, one becomes prepared to accept change in the future.

Only history clearly reveals the true nature of science. Students who fail to understand the nature of scientific progress will also fail to understand that:

* Science is an endless frontier.

* Ideas are necessary, but must be continually questioned.

* Scientists are bumblers who make progress only when they recognize their mistakes and adjust for them rather than defending them.

* Instruments are not only essential to scientific research, but an appropriate new tool can contribute to an impressive advance in understanding.

* Important scientific discoveries are frequently made simultaneously, but independently, in different laboratories. Only

rarely is plagiarism involved. When the background knowledge is complete, the subsequent discovery is almost inevitable (10).

References and Notes

Presented as a Perspectives Lecture to the Division of Chemical Education at the 198th National Meeting of the American Chemical Society in Miami Beach, FL, 10-15 September 1989.

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JEAN-BAPTISTE DUMAS (1800-1884): THE VICTOR HUGO OF CHEMISTRY

Ben B. Chastain, Samford University

Romanticism is the term used to gather together a whole series of literary and artistic movements of the late 18th to late 19th centuries. These various movements, which spread throughout Europe and even to America, had one common element - the rejection of the traditions and rules of classicism, of the "Establishment", as it were. Romanticism produced Wordsworth, Keats, and Shelley; Goethe and Heine; Hugo and Dumas (Alexandre, that is); Pushkin; and Poe. It produced Delacroix, Constable, and Turner; Schumann, Chopin and Liszt; and, of course, Wagner, who tried to put it all together in his musical dramas. The Romantics' emphasis on emotion over reason, and on subjectivity and imagination over objectivity and intellect, would seem to rule out any inclusion of the sciences in these movements. But we know better. We know that science is not just a collection of facts and techniques; that it is a human endeavor, carried out in the context of a specific society or culture. We know that scientists are not (or at least not always) one-dimensional, narrowly trained and focused, and cooly objective; but are three-dimensional human beings with interests in, and with attitudes affected by, the arts, literature, religion, and politics.

In that wonderful volume of biographical essays, *Great Chemists*, edited by Eduard Farber, there is a short piece on Jean-Baptiste Dumas and Charles-Adolphe Wurtz, written by Georges Urbain and first presented to the Société Chimique de France in May of 1934. Urbain gave an unusual and provocative summary of his two subjects when he wrote (1):

> Living in the brilliant period of romanticism, they did not escape its influence. Dumas was the Victor Hugo of chemistry and Wurtz its Sainte-Beuve.

Because I knew a bit about Hugo, my first reaction to this statement was perhaps a little odd: I wondered whether Wurtz had tried to steal Dumas' wife (as Sainte-Beuve did to Hugo). I have seen no evidence that this was the case; apparently all that was implied was that Wurtz was a pupil and a friend of Dumas. The parallels between Wurtz and Sainte-Beuve will have to await another paper. But the statement intrigued me. In what sense was Dumas the Victor Hugo of chemistry? This essay is my attempt to answer that question.

There are, in fact, a number of parallels in the lives of these two men (2,3). First of all, they were almost exact contemporaries; Dumas was born in July 1800, 19 months before Hugo, and died in April 1884, 13 months before Hugo. Their childhood and adolescence spanned the rise and fall of Napoleon I. Hugo's father was an officer in Napoleon's army; Dumas at the age of 14 was determined to join the navy, but was

Jean-Baptiste Dumas

prevented by the upheavals of 1814-1815 (Napoleon's abdication, exile, escape, and Waterloo).

Both men showed early signs of brilliance. Hugo's poetry won the recognition of the French Academy when he was just 15; Dumas' name appeared on many journal articles (in pharmacy and physiology) before he was out of his teens.

Both had wide-ranging talents and interests. Indeed, it can be argued that neither man's most important work is widely known today. To the general public (certainly in the English-speaking world) Hugo is most famous for two novels - *Notre Dame de Paris* with its hunchbacked bellringer Quasimodo, and *Les Miserables* (especially since it has been given a musical score in a pop soft-rock idiom). But it was Hugo's plays which established him as the leader of the Romantic movement in France, and it is his poetry which makes secure his exalted position in French literature. We know of his plays mainly because Verdi chose two of them as the basis for his operas - *Le Roi s'amuse* became *Rigoletto* and *Hernani* became *Ernani*. The poetry, however, apparently loses too much in translation, since it is almost unknown in English.

To the general chemical public of today, Dumas is known for two analytical methods which he developed or refined - one for the determination of molecular weights by vapor density and the other for the determination of nitrogen in organic compounds. Yet he was also a brilliant teacher. He held professorships at the Athanaeum, the Sorbonne, the École Polytechnique, and the École de Médecine (some simultaneously) and was a prolific writer on many philosophical and scientific subjects. Indeed, it is his work on the theory of organic chemistry which secures his place in the history of chemistry.

Both Hugo and Dumas became famous and widely known in the intellectual circles of their day when they challenged the Establishment, the orthodoxies of their respective fields. Though the Romantic movement in literature had begun in France with Mme. de Stael and Chateaubriand, the official model for poetry and drama was still the pseudo-classicism of Voltaire. Then, in the Preface to his 1827 play *Cromwell*, Hugo produced an extensive and strongly argued manifesto for romanticism in which he claimed that in the progression of man from the primitive to the civilized modern, romanticism was historically inevitable - a new phase in social evolution. The result was that, suddenly, at the age of 25, Hugo was freely acknowledged as the leader of the Romantics in France.

Chemistry, in its modern sense, was a relatively young science in the 1820s; Lavoisier and his followers had set it on its feet only a generation earlier. But, like literature, it had its orthodoxy, its official models, too. In molecular structure, there was the electrochemical dualism of the great Swedish chemist Berzelius. Briefly, this explained chemical combination by assuming that atoms had electrical polarity.

Oxygen was the most negative atom, potassium the most positive, with the others falling between. In general, metals were positive and even when they combined with oxygen, the oxide showed a residual positive character:

$$K(+) + O(-) \rightarrow K_2O(+)$$

Nonmetals might be positive toward oxygen, but negative toward metals. Nonmetal oxides always showed negative character:

$$S(+) + O(-) \rightarrow SO_3(-)$$

Salts were the result of the combination of positive metallic oxides with negative nonmetallic oxides, but were not necessarily neutral:

Victor Hugo caught in a characteristic pose at
the Académie française by the caricaturist Mérimée

$K_2O(+) + SO_3(-) \rightarrow K_2O{\cdot}SO_3(+)$ or $K_2SO_4(+)$

Double salts, like the alums, were seen as the combination of a positive and a negative salt:

$K_2SO_4(+) + Al_2(SO_4)_3(-) \rightarrow KAl(SO_4)_2(+)$

As can be seen, this is not all that different from our current concepts of electronegativity and simple acid-base theory. But in the growing field of organic chemistry, difficulties arose.

The use of the term "radical" to designate atoms or groups of atoms that acted as a unit in chemical combination, had been around since the 1787 book on nomenclature by Guyton de Morveau et al. (4). In 1817 the dualistic theory was extended by Berzelius to organic compounds (5):

> All organic substances are oxides of compound radicals. The radicals of vegetable substances generally consist of carbon and hydrogen, those of animal substances of carbon, hydrogen, and oxygen.

In 1827-28, Dumas and Polydore Boullay (a pharmacist) advanced the suggestion that compounds related to alcohol might be understood as addition products of ethylene (etherin), just as ammonium compounds were addition products of ammonia (Table 1). They even concluded that ethylene was a base, and would show the same alkaline behavior as ammonia if only it were soluble in water. All this was explained in dualistic terms (it was Berzelius who named the radical etherin) but the continuing search for and study of other hydrocarbon "radicals" caused much confusion, and led ultimately to the downfall of the dualistic model (6).

Table 1. The Etherin Theory of Dumas and Boullay (1828)

"etherin"	C_2H_4	ammonia	NH_3
alcohol	$C_2H_4{\cdot}H_2O$	hydroxide	$NH_3{\cdot}H_2O$
ether	$2C_2H_4{\cdot}H_2O$	oxide	$2NH_3{\cdot}H_2O$
chloride	$C_2H_4{\cdot}HCl$	chloride	$NH_3{\cdot}HCl$
nitro-	$C_2H_4{\cdot}HNO_2$	nitrite	$NH_3{\cdot}HNO_2$
acetate	$C_2H_4{\cdot}C_2H_4O_2$	acetate	$NH_3{\cdot}C_2H_4O_2$

Jöns J. Berzelius

In 1834 Dumas caused great consternation - wrote his "Cromwell Preface", though he didn't recognize it fully at the time - by proposing his "Law of Substitution". As the story goes, there was a ball held at the Tuileries in Paris, and fumes given off by the candles caused the guests to cough and choke. The King asked his friend Alexandre Brogniart, director of the testing laboratories of the royal porcelain works at Sévres, to investigate. He passed the problem on to his son-in-law, Jean-Baptiste Dumas, who soon identified the irritant as hydrogen chloride, the candle wax having been bleached with chlorine. He made further studies of the chlorination of waxes, oils, and the like, and found that chlorine was absorbed and hydrogen chloride emitted in equal amounts. He also looked at Liebig's discovery of the two-stage reaction between chlorine and alcohol (viewed as a hydrate of etherin) to produce chloral:

$$C_2H_4{\cdot}H_2O + Cl_2 \rightarrow C_2H_4O + 2HCl$$

$$C_2H_4O + 3Cl_2 \rightarrow C_2HCl_3O + 3HCl$$

As a result of these studies, he stated his law of substitution:

> * When a substance containing hydrogen is exposed to the dehydrogenizing action of chlorine, bromine, or iodine; for every volume of hydrogen that it loses, it takes up an equal amount of the halogen.
> * When the substance contains water, it loses the hydrogen corresponding to this water without replacement.

Note that in the oxidation of alcohol to aldehyde, the chlorine removes the oxygenated hydrogens without substitution, but in the second reaction to produce chloral (trichloroacetaldehyde) the chlorine atoms substitute one-for-one the hydrogens attached to carbon. Dumas even went further and considered the oxidation of alcohol to acetic acid as a substitution in which each hydrogen is replaced by one-half atom of oxygen:

$$C_2H_4{\cdot}H_2O + O_2 \rightarrow C_2H_4O_2 + H_2O$$

These ideas were taken up by other chemists, especially Auguste Laurent. Now Berzelius was not at all happy with this theory, for it seemed to imply that electropositive hydrogen could be substituted by electronegative oxygen or halogens without any drastic alteration in the structure, and his dualism would not allow this.

Then a few years later (1839), Dumas reported that he had taken the known reaction in which trichloroacetic acid is decomposed into chloroform and carbon dioxide and repeated it with acetic acid, producing methane and carbon dioxide:

$$CCl_3CHO_2 + \text{alkali} \rightarrow CO_2 + CHCl_3$$

$$CH_3CHO_2 + \text{alkali} \rightarrow CO_2 + CH_4$$

Here chlorine and hydrogen obviously play the same role. The theory of types, as it became known, was a definite challenge to the dualism of Berzelius, for it considered molecules to be unitary structures whose properties depend on the position and arrangement of the atoms rather than their intrinsic positive or negative character. The battle raged between the classical dualists and the revolutionary unitarians with the French chemists largely championing the unitary theory and Dumas as their acknowledged leader. (There was also a rather nasty internal argument between Dumas and Laurent as to which of them really originated the type theory, but that's another story.)

Hugo and Dumas each belonged to the appropriate prestigious French Academy and Dumas was eventually made permanent secretary of the Academie des Sciences. Both men were egotists and were not above using their positions and prestige for their own purposes. Dumas was practically the dictator of French chemistry from 1840 to about 1865. He was responsible for the "exile" from Paris to provincial universities of Auguste Laurent, Charles Gerhardt, and others with whom he quarreled. Hugo in his later years became an insatiable womanizer, bedding chambermaids, leading actresses, and great ladies who found him, or rather his aura of literary demigod, irresistible. But let's be more positive.

Both Dumas and Hugo devoted large portions of their lives to politics and public service and made important contributions to life in France quite aside from their major fields of endeavor. Despite the high position his father had held under Napoleon, Victor Hugo was in his youth a firm Royalist and had been given a sort of fellowship (a pension) by the King so that he could devote himself to his writing. But his political views began to shift, especially after the July Revolution of 1830 in which Charles X was replaced by Louis-Phillipe. His writings became more liberal and more republican. Some of his friends were shocked in 1845 when he became a Peer of France (was appointed to the House of Lords) and felt that he was betraying his beliefs for the sake of position. However, he proved to be politically independent and actually had more contact with the leftist utopian reformers than with the moderates. After the 1848 Revolution and the establishment of the Republic, Hugo campaigned as a middle-of-the-road independent and was elected to the new Assembly along with a man who had just returned to France, one Louis-Napoleon Bonaparte (nephew of the late Emperor). He backed Louis in his campaign for the Presidency of the Second Republic, but when, after his election, Louis began to follow in his uncle's footsteps and undermine parliamentary rule, Hugo turned against him. When Louis was declared Emperor Napoleon III in 1851, Hugo had to flee for his life. He lived first in Brussels, then in the Channel Islands, which belong to England but lie within sight of France. On the Isle of Guernsey he wrote poetry, novels (including *Les Miserables*), and some anti-Imperial broadsides. He returned to France in 1870 during the tumultuous birth of the Third Republic and moved back permanently in 1873 to live out his years as the "Grandpere", the Grand Old Man, revered by all. He continued to write, mostly poetry, until his death in 1885.

Dumas caricaturized by Honoré Daumier

Dumas' political career did not really begin until almost all his scientific work had been accomplished. By 1840, as we have seen, he was the most powerful chemist in the country. His politics had been moderately conservative; he had prospered under the Monarchy. But after the 1848 Revolution he, like Hugo, was elected to the Assembly, and he served as Minister of Agriculture from 1850-1851. Unlike Hugo, he backed Louis-Napoleon and became a Senator in the Second Empire. He was on the Municipal Council of Paris for many years and became its President (in effect, the mayor) in 1859.

During his administration, the drainage and lighting systems of the city were greatly improved and work was begun on the system of aqueducts and tunnels to supply Paris with spring water. In 1870, the upheaval which brought Hugo back to France led to the resignation of Dumas from public service and his return to chemistry. He too remained active almost until his death, publishing papers on topics such as fermentation and the occlusion of oxygen in silver.

It seems to me that there are enough parallels to make a good case for Urbain's statement. Let me close with a curious twist. In *Les Miserables* there is a character called Grantaire who drinks a lot and, when in his cups, is given to eloquent flights of discourse, ranging over history, philosophy and, in at least one instance, science. In Part Four, Book XII, Chapter 3, he says (7):

> Comrades, we're going to throw out the Government and that's the truth, as true as the fact that between margaric acid and formic acid there are 15 intermediate acids. Not that I care a straw about that. My father always abominated me because I couldn't understand mathematics.

Now *Les Miserables* was written in 1862. In 1842, three years before Gerhardt coined the phrase "homologous series" for sets of compounds whose composition differed only by a multiple of CH_2, Dumas had shown that such a relation exists among fatty acids, and in his paper had affirmed that between formic and margaric acids there were exactly 15 intermediate acids, of which nine were known at that time and six remained to be found (8). Dumas, as an educated man of his time, must have almost certainly read Hugo's works and, as the above quote suggests, it seems that the converse must also be true!

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VICTOR SERRIN AND THE ORIGINS OF THE CHAINOMATIC BALANCE

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With a history of thousands of years, the conventional, or two-pan, balance is known to everyone; it is the symbol of justice. Various forms of this instrument are in worldwide use, although the so-called single-pan balance and, latterly, the electronic balance, have largely displaced the two-pan version in the laboratory.

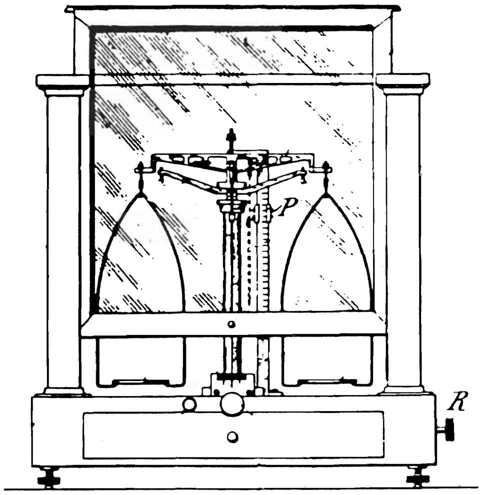
Trade in small but valuable objects, such as gemstones and gold coins, encouraged the development of the balance. Instruments of quite high sensitivity were in use by the 16th century. The introduction of regional or national standards of weights and measures further emphasized the need for precision balances, taxing the skill of 18th- and early 19th-century instrument makers such as Jesse Ramsden (1), Thomas Robinson (2), and Henry Barrow (3).

Instruments designed for chemical work are routinely expected to be able to detect a mass difference of one part in a million. For a 100-gram maximum load, this means weighing to the nearest 0.1 milligram. The results obtained in the use of even the finest two-pan balance depend ultimately upon the self-consistency and accuracy of the associated standard weights. These are added or removed by tweezers. However, very small weights are difficult to handle in this fashion and are easily lost. Conventionally, this problem is minimized by the use of a "rider" that can be suitably placed on a graduated scale on the beam of the balance. For example, a 10-milligram rider placed very near to the center knife or fulcrum of the beam could exert the same turning force as a 0.3-milligram weight that was placed directly on the balance pan. Manley (4) attributes the introduction of the principle of the rider to Berzelius. It is certain that British balance maker Ludwig Oertling received a medal for his balance "with graduated beam and sliding apparatus", shown during the 1851 Great Exhibition in London (1).

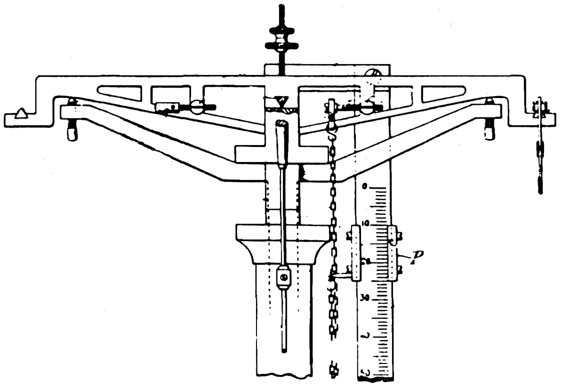
A later solution to the problem is the utilization of a fine chain. One end of this hangs from a grooved screw that is suitably mounted on the right-hand half-beam. The other end is attached to a hook on a carriage that can traverse a graduated vertical column standing just in front of the beam. An adjustable counterweight on the left-hand half beam compensates for the turning force of the chain when the carriage is at the zero mark near the top of the column. As the carriage is lowered, more of the total length of the chain exerts a turning force on the beam. Typically, the range covered by full travel of the carriage is zero to somewhat greater than 100 milligrams. In the associated box of weights, the smallest of these is one decigram.

A patent for this type of balance was granted to Christopher A. Becker in 1916 (5). The illustrations for Becker's patent show both a general view of the balance and the details of the beam. Attached to the carriage is a pin that engages a spiral groove in a vertical spindle. This can be rotated through bevel gearing by a knob on the outside of the balance case, allowing the carriage to be positioned to bring the balance to equilibrium after the case has been closed. This type of balance, known as "chainomatic", was commercialized in the United States and also by L. Oertling, Ltd. in Britain (6).

The general impression is that the chain balance originated in the United States (6-9). However, a text of 1899 (10) refers to the "Chaîne Serrin", which appears to be very similar to the arrangement described by Becker seven years later (5). In fact, the Frenchman, Victor Serrin (b. 1829), gave a concise description of the chain balance in *Comptes Rendus* as early as 1891 (11). Since he was apparently not a member of the "Academie"; his notice was presented by Janssen. Serrin's subsequent patent (12) indicates applications of the "chaîne", which he termed "pondérateur", to various measuring instruments. The figures from this patent show three versions of the chain balance. The first employs a vertical carriage column, while the second has a pulley to permit horizontal travel of the carriage. In the third, the column and carriage are replaced by a graduated drum on which the chain is wound. Also shown are arrangements for measuring the force exerted by a solenoid, a Prony-brake device for mechanical forces, and a system for barometric measurements. In all cases, the chain is shown attached to one end of the beam. However, these figures are obviously diagrams and not illustrations of actual devices.



Becker's "Chainomatic" balance of 1916 (5)



Close-up of the chain mechanism for Becker's balance (5)

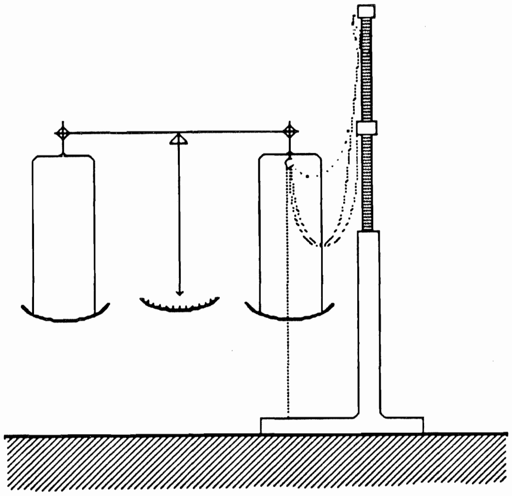
Becker's patent contains the following statement (5):

> In scales or balances having a counterbalancing chain as heretofore proposed, the adjustable or dead end of the chain has been hung to a slide having a frictional engagement with a vertical guiding part and being moved up or down by the direct manipulation by the hand of the operator... Such construction if applied to an inclosed balance would require re-opening its case for each adjustment, and the necessity for this deprives the chain type of balance of any material advantage over those requiring manual adjustment of a counterpoising weight or weights. The present invention, by providing for an adjustment of infinite nicety which admits unprecedented rapidity in counterpoising, and which in an inclosed balance may be accomplished from the exterior without opening the casing, provides a scale or balance having important practical advantages over any weighing means heretofore used.

It is true that Serrin's 1891 paper has no diagrams. However, it contains the sentence (11, 15):

> The chain is easily moved from outside of the case by means of a special button, in such a way that when a weighing has been approximated to the nearest 1 mg, it is no longer necessary to open the case to complete the operation.

The 1899 account of the "chaîne Serrin" includes the illustration of a chain-type balance carrying the inscription "A. DEMICHEL, PARIS" (10). The movement of the chain



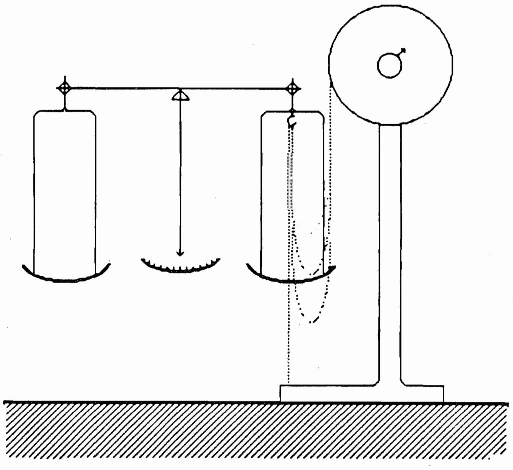
Serrin's vertical carriage design, redrawn from (12)

carriage is definitely operable from outside the case. Apparently, the chain is suspended from the beam at a point quite close to the center knife, as in the Becker balance.

A 1901-2 listing of French instrument makers (13) indicates that A. Demichel had taken over the business founded by J. Salleron in 1855. Demichel made a wide variety of physical and chemical apparatus, as well as marine and meteorological instruments.

Although the chain balance system is simple, the precise underlying theory is not. This aspect has been examined by W. Uhink, of Sartorius, a famous balance-making firm (14). He derived formulas for the calculation of errors and evolved methods for the essential elimination of these.

A need to evaluate many thousands of ancient weights led to the application of the chain principle to a massive form of balance (9). One end of the brass chain is attached to the pan that carries the standard, or modern, weights; a precision of about 10 milligrams is claimed.



Serrin's graduated drum design, redrawn from (12)

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Acknowledgment: Part of this work was carried out under the Research Fellowship Program of the Science Museum, London.

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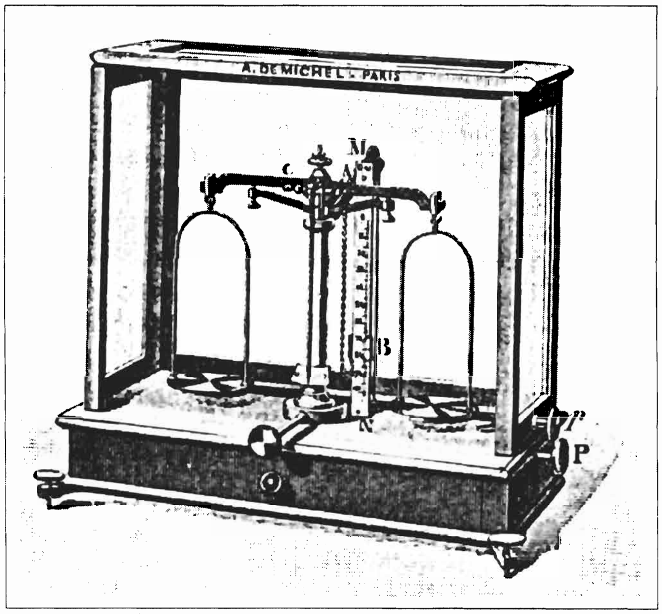

A French chain balance, circa 1899 (10)

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LAURA ALBERTA LINTON (1853-1915): AN AMERICAN CHEMIST

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American women chemists publishing without a male coauthor in the years before 1900 form a rather select group, and if we exclude those whose only single-author publication was Ph.D. dissertation research, the number becomes even smaller (1). Of the independent workers who make up this remaining group, a few are well known in the story of women scientists in America: one might name, for instance, Ellen Swallow Richards of MIT, whose early papers in analytical chemistry (2) date back to the mid-1870s, Helen Abbott-Michael, author of several papers on the chemical identification of plant constituents (3), and Ida Keller, another plant chemist (4). However, in the early volumes of the American chemical journals there are also less well-known names, and one of these is Laura Alberta Linton.

Laura Linton published two substantial papers on the analysis of asphalt samples in the *Journal of the American Chemical Society* in 1894 and 1896 (5). The publications appearing in this journal in its early years were somewhat uneven in quality and scientific content, but the two papers by Linton stand out for the amount of careful analytical work they record and the clarity and directness of their presentation. Furthermore, we know that they were received by the chemical community with some interest, and were considered important contributions to the field. Linton says in the introduction to her second (1896) paper that she was encouraged to present more results and to indicate new developments in her analytical methods, because of the favorable reception accorded her 1894 publication. An extensive discussion followed the oral presentation of the 1896 paper at the Cleveland meeting of the American Chemical Society in December 1895, the participants clearly recognizing the commercial importance of asphalt. In 1896 Linton published one other paper (6), jointly with the petroleum chemist Stephen F. Peckham. After that her name disappears from the chemical literature.

Laura Alberta Linton

Who was Laura Linton? She was born in Mahoning County, Ohio, 8 April 1853, the oldest child in the Quaker family of Joseph and Christiana Linton (7). The Lintons farmed in Ohio, Pennsylvania and New Jersey, and finally settled in Wabash County in southern Minnesota in 1868. Laura graduated from Winona Normal school in 1872, and enrolled at the University of Minnesota in Minneapolis the same year. Chemistry became her major interest.

In her senior year Linton was given the job of analyzing some mineral specimens collected along the northern shore of Lake Superior by two faculty members, Stephen Farnum Peckham and Christopher W. Hall. The small, translucent, green pebbles she investigated were chemically very similar to thomsonite, a silicate of calcium, sodium and aluminum, but Peckham and his co-worker concluded, mainly from differences in the crystalline structure and the unusual color, that they had found a distinct variety of thomsonite. They gave it the name *Lintonite*, "in honor of Miss Laura A. Linton, a recent graduate of this University to whose patient effort and skill we are indebted for the analysis given in this paper" (8).

Linton graduated with a B.S. from the University of Minnesota in 1879, and then taught for a year at the high school in Lake City, Minnesota. Around this time Stephen Peckham had undertaken the preparation of a report for the 1880 United States Census on the *Production, Technology and Uses of Petroleum and its Products*, and he invited Laura Linton to help him in this work. Peckham's report, an impressive monograph of 301 pages plus 30 plates, provides a comprehensive history of the discovery of petroleum world wide and makes extensive use of source materials in foreign scientific journals. The chemistry of petroleum and the bitumens is discussed, along with methods of oil production, transportation and storage, the technology of petroleum (distillation, "cracking", and so on), and finally the possible uses of petroleum. Peckham expresses his "obligations to Miss Laura Linton, who has assisted me in the preparation of this report, and to whose varied accomplishments I am indebted for many of the translations and illustrations that add completeness and embellishment to the work" (9). Clearly Laura Linton was well acquainted with the literature on petroleum chemistry when she came to do her research in this area 15 years later.

The preparation of the monograph took two years. Following that, in 1882, Laura Linton registered at MIT, where she studied chemistry for two semesters in 1882-83. It seems likely that she would have worked in the Woman's Laboratory, which operated until 1883 under Ellen Swallow Richards' direction. Dahlberg (10) believes that Linton expected to remain at MIT and to graduate (11), but the offer of a faculty position at Lombard University in Galesburgh, Illinois (13) led her to put aside her graduate studies. And thus, at age 30, Linton became Conger Professor of Natural Science at Lombard University (14). She remained there for only one year, however, and then in 1884 she moved back to Minneapolis to become head of the science department in Minneapolis Central High School.

A view of the Woman's Laboratory Class for the Lowell Institute, circa 1869. This became the Woman's Laboratory of MIT in 1876.

Around 1894, following 10 years of high school teaching, Linton returned to research in chemistry, and it was at this time that she carried out her work on asphalt analysis. She obtained her asphalt samples from Stephen Peckham, who had connections with the Union Oil Company of California, and who was superintendent of that company's Santa Paula refinery for six or eight months during 1894-95. Indeed, Linton states that she did the work described in her 1894 paper in the laboratories of the Union Oil Company. Since the Santa Paula laboratory was the only laboratory operated by the Company at that time (15), she must have gone out to California. A woman chemist working in an oil company laboratory would have been rather rare in 1894, but Linton was an unusual woman, possessing, as Peckham had remarked, "varied accomplishments" (9). Part of the asphalt research was carried out at the University of Michigan, where Linton was enrolled for the year 1895-1896, and during this time she published, jointly with Peckham, her third paper on asphalt analysis (6). Then she left chemical research, and, returning to Minneapolis, enrolled in the College of Medicine at the University of Minnesota. In 1897 she served as Instructor in Physiology, teaching "Physiologic Chemistry" in the College of Medicine (16). She graduated with an M.D. in 1900.

One might wonder why Linton gave up chemistry for medical school just after the publication of her well-received research work. Did she perhaps share some of Ellen Swallow Richards' views (17) that chemistry was a difficult field for women to succeed in? Why had she never completed a graduate degree in chemistry? The latter was clearly within her grasp as far as research abilities were concerned, and its lack was doubtless an additional handicap (beyond that of being a woman) to finding a fulfilling academic position. On the other hand, she may have had more positive reasons for her change of field (18); her family seems to have been strongly drawn towards medicine. Her brother, Thomas Linton, and her sister, Sarah Linton Phelps, were physicians, Sarah having graduated from the Woman's Medical College of Philadelphia (10).

Whatever the reasons for her switch, Linton spent the rest of her life as a physician. She joined the staff of the State Mental Hospital in Rochester, Minnesota, immediately after her graduation in June 1900, and she rose to the position of assistant superintendent in charge of the women's wards (19). She was responsible for introducing one of the earliest known attempts at occupational therapy (a program of needlework and handicrafts for women patients). She also undertook the teaching of a course on dietary principles coupled with practical cooking methods in the nurses' training school of which she was one of the heads (20). This was long before such material was included in standard nurses' training (10). She remained on the staff of the hospital until her death on 1 April 1915.

In an obituary (21) she is remembered as leading a full life "of service in the teaching and medical professions"; her research work in chemistry is not mentioned. Nevertheless, at one time or another, she was engaged in all the activities we expect of a successful scientist of that day: teaching (at college level), research, and the publication of results in scientific journals. Laura Linton was clearly an active, involved member of the scientific community of her time and attuned to the current ideas. She was a member of the American Association for the Advancement of Science, and the American Association for the Advancement of Women. (She also served as State Chairman for Electricity at the Chicago World's Fair in 1893 (10).) In her chemical career, however, she never obtained a position where she could unite her teaching and research activities. As a chemist she has gone unremembered - until now.

Finding a satisfactory career in scientific work was a major problem for women science graduates, then as later. Higher education in scientific fields had opened up to women by the 1880s, and even graduate degrees were possible by the nineties, but strong resistance was concurrently developing to women entering traditional kinds of scientific employment, such as university teaching and government work (22). A capable and ambitious woman science graduate, whose aspirations reached beyond high school teaching or a career as a low-paid research assistant, had a limited range of opportunities available to her: a faculty position in a women's college was one option, but these openings were few; administrative work as dean of women in one of the newly-established co-educational state universities was another possibility; a third was a move into "women's work" in science, in the newly-created, segregated, low-status fields such as hygiene, physical education, or home economics.

Of the early women chemists, a considerable number found careers in home economics, where independent work was possible and normal advancement could be expected. Linton's career in the medical profession offered her similar advantages: here she had scope for innovative work and for the exercise of her leadership capabilities beyond anything a woman could have reasonably expected in chemistry.

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7. We are especially indebted to Beverly Hermes, Librarian of the Olmsted County Historical Society, Rochester, Minnesota, and to Patricia Harpole of the Reference Library of the Minnesota Historical Society, St. Paul, Minnesota, for biographical information on Laura Linton. They provided copies of obituaries and of two articles by Jean C. Dahlberg: "Laura A. Linton and Lintonite", *Minnesota History*, **1962**, *38(1)*, 21-23, and "A Woman to Remember", *Lapidary Journal*, **1976**, *29(Oct.)*, 1732-1736. We also wish to thank Nancy Bartlett, of the Bently Historical Library, University of Michigan, and Carol Bohlman, University Archives, University of Minnesota, Minneapolis, for information from their records. Mark A. Vargas of the Institute Archives at MIT provided dates, and Carley R. Robison, Archivist at Knox College, Galesburgh, Illinois, gave us copies of records. Finally, Robert J. Endecavageh of the Unocal Corporation, Los Angeles, provided information about the Union Oil Company laboratory facilities in 1894-1896, and about Stephen Farnum Peckham's relationship to the Company.

Some information about Laura Linton is to be found in F. E. Willard and M. A. Livermore, eds., *A Woman of the Century: Biographical Sketches ... of Leading American Women,*, New York, 1893; republished by Gale Research Co., Book Tower, Detroit, 1973, as *American Women, a Revised Edition of "Woman of the Century"*.

8. S. F. Peckham and C. W. Hall, "On Lintonite and Other Forms of Thomsonite: A Preliminary Notice of the Zeolites in the Vicinity of Grand Marais, Cook County, Minnesota", *Amer. J. Sci.*, **1880**, *19*, 122-130.

9. S. F. Peckham, *Production, Technology, and Uses of Petroleum and Its Products, VIII*, United States Census, 1880. (Tenth Census of the United States, Vol. X). Laura Linton could read French and German and was a competent technical draughtswoman (see Dahlberg, reference 10).

10. J. C. Dahlberg, "A Woman to Remember", *Lapidary Journal*, **1976**, *29(Oct)*, 1732-1736.

11. It is unclear what degree Linton would have received from MIT. Ellen Swallow (Richards), with a bachelor's degree from Vassar, had applied to MIT in 1870 for admission to the graduate

program in chemistry, but had had to settle for being a candidate for a second bachelor's degree (Rossiter, reference 12, pp. 30-31).

12. M. W. Rossiter, *Women Scientists in America. Struggles and Strategies to 1940*, Johns Hopkins, Baltimore, MD, 1982.

13. Lombard University, a Universalist college and theological school, merged with Knox College during the Depression. We thank Carley R. Robison, Knox College, for this information.

14. *Catalogue of the Officers and Students of Lombard University, Galesburgh, Illinois, for the Year Ending June 18, 1884.*

15. Personal communication from Robert J. Endecavageh, Unocal Corporation, Los Angeles.

16. Anon., "College of Medicine", *Ariel* (College of Medicine, University of Minnesota), **1897**, *20*, *No. 33(June)*, 34.

17. For a discussion of the precarious position of women scientists in academia at this period, and Ellen Swallow Richards' experiences in particular, see Rossiter, reference 12, Chapter 3, "Women's Work in Science".

18. Linton, however, was hardly putting aside chemistry for any "soft" alternative; even in 1896, two decades or so after the first of the pioneering generation of women students (including some Americans) had made their way into the medical schools of Switzerland and France, setting out to get an M.D. was no small challenge for a woman.

19. Anon., "Dr. Laura Linton Dies at Rochester", obituary in *Minneapolis Journal*, **1915**, *April 2*.

20. It was about this time that Ellen Swallow Richards was founding the field of Home Economics, and stressing the importance of dietary studies (Rossiter, reference 12, p. 69). It is tempting to postulate some influence from the older woman's thinking on Linton's undertakings.

21. Anon., "Useful Life is Ended", obituary in *Rochester Post and Record*, **1915**, *9 April*.

22. See Rossiter, reference 12, chapter 3, and also L. B. Arnold, *Four Lives in Science. Women's Education in the Nineteenth Century*, Schocken Books, New York, 1984, especially Chapter 6.

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OLD CHEMISTRIES

John Penington's "Chemical and Economic Essays"

William D. Williams, Harding University,
and Wyndham D. Miles, Gaithersburg, MD

1990 marks the bicentennial of a unique early American chemistry book. When John Penington's *Chemical and Economical Essays* (1) was published in 1790, George Washington was in the second year of his presidency. The contemporary chemist, James Cutbush, called Penington's work "the first chemical book published in the United States" (2). That statement is not literally true. While there were American imprints on chemistry prior to 1790, Penington's *Essays* may be labeled the first full-size book devoted only to chemistry (3). In addition to reviewing Penington's *Essays*, this paper will present some unpublished material from a journal he kept while studying in Europe.

John Penington was born in Philadelphia on 29 September 1768, the son of Edward and Sarah Penington (4). A dedicated, disciplined young man, he packed considerable experience into a short 25-year lifetime. In addition to writing America's first chemistry book, he was the founder and president of America's first chemical society and, 70 years before Pasteur, devised a method of heat-preserving milk. Penington grew up in a period when Philadelphia was the center of governmental, intellectual and scientific activity. Since his family appears to have been well-to-do, he probably associated with people we would now regard as historically famous.

Comments in his book suggest that Penington was involved in industrial chemistry as a youth. His interest in chemistry may have been initiated by the family-owned sugar works (5). In one of the later essays, written as he neared graduation from medical school, he remarked that he had "now in some measure left chemistry as a profession." He also indicated prior chemical experience by referring to "the path I have trodden" when describing sulfuric acid production (6).

As a medical student at the College of Philadelphia, Penington studied chemistry under Benjamin Rush in the winter of 1788-89 (7). This was the last year that Rush taught chemistry; he was succeeded by Casper Wistar, who offered the course from 1789 till 1791. Penington's intense interest in chemistry may have led him to also attend Wistar's lectures in 1789-90. In dedicating his *Essays* to Wistar, Penington wrote (8):

> To CASPER WISTAR, JUNIOR, M.D. AND PROFESSOR OF CHEMISTRY in the College of PHILADELPHIA, The Friend and Patron of CHEMICAL INQUIRIES IN AMERICA, These Essays are inscribed, by His sincere friend and pupil, JOHN PENINGTON. Philadelphia, May 25, 1790.

In a newspaper article on the history of chemistry in Philadelphia, James Cutbush reported Penington's activities in the first American chemical society (9):

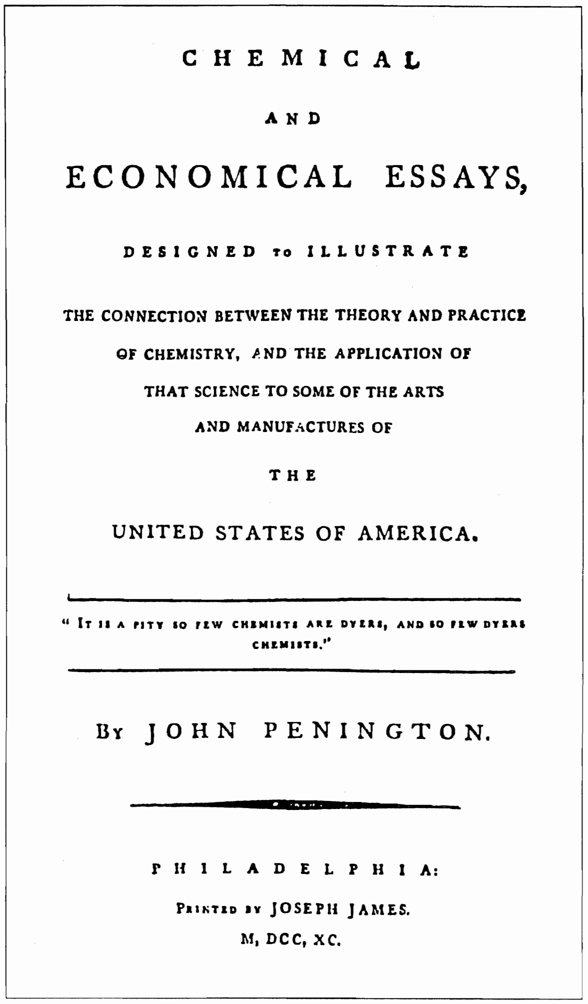
> During the spring of the year 1789, in consequence of the efforts of the late Dr. J. Pennington [sic], a chemical society was formed, and the doctor was elected to the presidency; whose duty it was to deliver discourses on chemical subjects. This was performed with great ability; each subject was illustrated by experiments, with much

success on the part of the president and with considerable benefit to the members of the society.

In the preface of *Essays*, Penington explained that his book began in 1789 as a series of articles in the *Columbian Magazine*. When asked to contribute "useful hints and recipes," he chose rather to "illustrate the connection between rational chemistry and many of the useful arts." The articles were discontinued after only four were published because they had such a restricted readership (10). The printer, however, offered to publish the extended series in book form. It is remarkable that the 21-year old Penington was able to accomplish this task while simultaneously completing his medical education, which included research and the writing of a dissertation.

The 200-page book, bound in calf and costing one dollar (11), contained 17 topical essays and an appendix. The appendix was a reprint of Penington's M.D. thesis. Some essays have a textbook-like character and exhibit thoughtful explanations which suggest that Penington would have been a good teacher. Most of the essays, however, were devoted to industrial processes and emphasized the value of chemistry to society. If Penington were expressing his views in today's terms, he would be a strong advocate of R&D. A recurring theme was the admonition for the artisan and the scientist to unite their efforts in the laboratory. He argued that the artisan did not understand why he performed certain operations, while the theorist could explain the science, but lacked the talent to manipulate the process. This theme was expressed on the title page with the quotation, "It is a pity so few chemists are dyers, and so few dyers chemists."

The following letter by President Thomas Jefferson endorsed Penington's emphasis on practical chemistry (12):



CHEMICAL

AND

ECONOMICAL ESSAYS,

DESIGNED TO ILLUSTRATE

THE CONNECTION BETWEEN THE THEORY AND PRACTICE
OF CHEMISTRY, AND THE APPLICATION OF
THAT SCIENCE TO SOME OF THE ARTS
AND MANUFACTURES OF
THE
UNITED STATES OF AMERICA.

"IT IS A PITY SO FEW CHEMISTS ARE DYERS, AND SO FEW DYERS CHEMISTS."

BY JOHN PENINGTON.

PHILADELPHIA:
PRINTED BY JOSEPH JAMES.
M, DCC, XC.

Monticello, August 1805

Of the importance of turning a knowledge of chemistry to household purposes, I have been long 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 purpose of life; while the arts of making bread, butter, cheese, vinegar, soap, beer, cider, &c. remain unexplained. Chaptal has lately given the chemistry of wine making; the late Dr. Pennington [sic] did the same for bread, and promised to pursue the line of rendering his knowledge useful in common life; but death deprived us of his labors. Good treatises on these subjects should receive general approbation.

TH: JEFFERSON

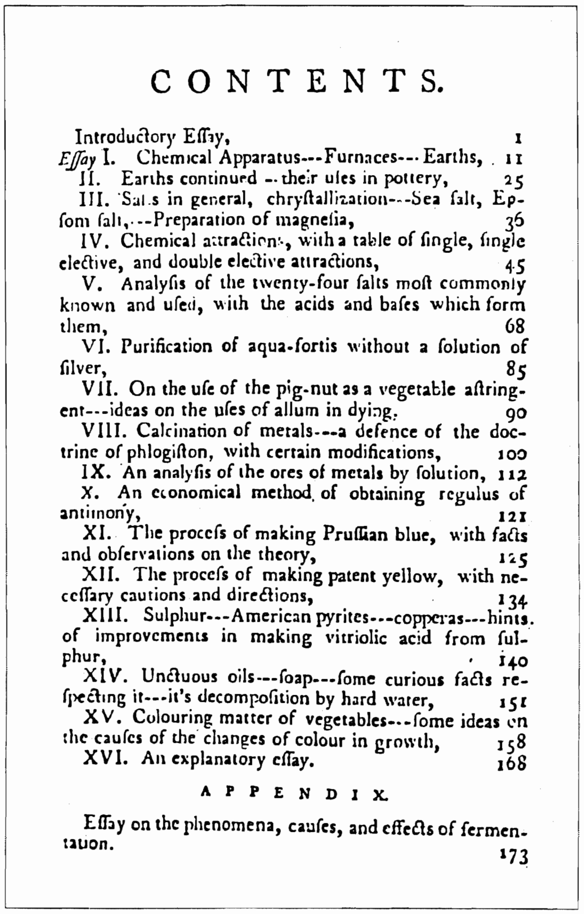
Patriotic comments were scattered among Penington's essays. He berated Americans for believing that imported articles were better than those made in America and he challenged American manufacturers to produce products equal to foreign ones. He repeatedly emphasized that a given chemical is the same whether made in America or imported. Penington apparently had access to a laboratory. He conducted his own research on purifying aqua-fortis (nitric acid), the use of pig-nuts in dyeing, and a fractional crystallization technique on salts of alkalis and marine (hydrochloric) acid. In the essay on the defense of the doctrine of phlogiston, he carefully reviewed the work of Stahl, Lavoisier, Priestley, Cavendish, Black, Bergman and Fourcroy. He spoke of his own experiments and concluded with his own modified theory of phlogiston.

He referred to Nicholson's *Philosophy*, Bergman's *Essays*, the *Edinburgh New Dispensatory*, and Fourcroy's *Elements of Natural History and Chemistry*. Two plates of Black's furnaces, taken from the *Edinburgh New Dispensatory*, and a table were mentioned in the text. These plates, however, were not present in the three copies of the book that we have examined. They had been included in the original *Columbian Magazine* articles. Although Rink (13) lists plates in his citation of this imprint, we are not sure whether they were present in any copy of the book.

Penington received his M.D. degree in June 1790. His *Inaugural Dissertation on the Phǿenomena, Causes and Effects of Fermentation* was the first thesis at the medical school printed in English rather than the customary Latin. The introduction explained that Franklin and Rush favored a modern language and that many scientific terms would not translate into Latin. A footnote quoted Dr. Rush as complimenting Penington's conclusions on fermentation and noted that Rush "adopted it and publicly taught it, with acknowledgments to the author" (14). This dissertation was reprinted as the appendix in Penington's *Essays*.

Two weeks after his graduation, Penington sailed for Europe, where he studied medicine and chemistry for two years in Edinburgh and Paris. Both Rush and Wistar had taken M.D. degrees at Edinburgh and had studied chemistry under Joseph Black. They probably had advised Penington to follow their path.

A journal that Penington kept while in Europe has survived (15) and is the source of the following information. He left Philadelphia on 17 June 1790 and landed at Greenock on 14 July. He presented letters of introduction from Wistar and Rush to Joseph Black. He dined frequently with Black, discussing many chemical topics, including the doctrine of phlogiston. He recorded that Black "professes to believe in the antiphlogistic doctrine of calcination" and "thinks that the phlogistians have adopted too many suppositions." While Penington did not indicate that he debated the topic with Black, he did strongly defend the phlogiston explanations at several scientific meetings. He spent time with fellow American, John Redman Coxe, who was also studying in Edinburgh, but soon decided to avoid Coxe because he found him to be "selfish and impertinent." He visited with Henry Moyes, the blind lecturer on chemistry, who had presented a series of chemical lectures in the United States in 1785-86. During the fall and winter of 1790-91 he attended lectures at the university. In his spare time he carried out chemistry experiments, attended the theater, visited chemical works and mines, and attended scientific meetings. In the summer of 1791 he went to Paris, where he spent time sightseeing and attending the lectures of Fourcroy and Brogniart. The journal ended in France on 19 August 1791.



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Penington's work on bread, which Jefferson's letter mentioned, was the subject of an entry in the journal (15):

> *November 6, [1790]* - With much pleasure I found in the No. of The Encyclopedia published today, that my ideas on the raising of bread have been adopted.

He was probably referring to conclusions reached in his *An Inaugural Dissertation*. He had concluded that, contrary to the then accepted explanation, yeast bread was not raised by fermentation. He described experiments proving that no vinous spirit (alcohol) could be distilled from a sample of rising dough. He found that it took more than 16 hours for true fermentation to furnish appreciable fixed air (carbon dioxide). Furthermore, he could cause bread to rise with dough made with natural carbonated water or with dough containing sodium carbonate crystals and hydrochloric acid. While these experiments and conclusions were sound, his explanation of what did cause the bread to rise was curious (16):

> Yeast is a fluid containing a large quantity of fixed air, or aerial acid ... as soon as the yeast is mixed with the dough, heat is applied; this extricates the air in an elastic state, and as it is now diffused through every particle of dough, every particle must be raised.

His method of preserving milk was described in a letter from Edinburgh to Benjamin Rush. He had prepared the milk before leaving on the month long voyage across the Atlantic and found it "as good at the end of the passage as when first put up." His process was given (17):

> Boil new milk with its own weight of loaf sugar for three quarters of an hour, stir gently during the operation and pour it, warm, into clean bottles.

This same letter gave an interesting comment on Penington's professors (17):

> Alas, dear sir, I despair of meeting a Rush, or a Wistar, here, it is not the character of the professors at Edinburgh, to take the youthful inquirer by the hand and accompany him in the road of true knowledge. Pride and reserve prevail among the professors, idleness and dissipation in the generality of the students, and for want of proper company, I have hitherto retreated to books and a solitary walk.

Penington returned to Philadelphia in 1792 and began a medical practice. His interest in chemistry continued, however, as evidenced by an announcement about potash which appeared in July 1793. Signed by Penington, Rush, Wistar, David Rittenhouse, James Huchinson and Benjamin Say, this article endorsed the Hopkins process for preparing potash and pearlash (18).

During the dreadful yellow-fever epidemic of 1793, when one fifth of the population of Philadelphia died, Penington continued to attend patients until he also succumbed. His death on 20 September 1793 was lamented in a letter written that same day by Benjamin Rush: "Poor Dr. Penington is no more. His death was occasioned by his going out too soon after his recovery." Rush later wrote (19):

> I must here pay a tribute to respect to the memory of my much loved friend Dr. Penington, who adopted the new remedies as soon as they were mentioned to him. His expanded mind was not cast in a common mold. It vibrated in unison with truth the moment it came in contact with it.

A local newspaper eulogized (20):

> Had the present malignant fever deprived the city of Philadelphia of the genius, knowledge, and virtue of this one excellent physician and citizen only, it would be a calamity to be deplored for many, many years to come.

If Penington had lived, he might very well have become Professor of Chemistry at the University of Pennsylvania. Benjamin Rush exercised a prime influence upon the appointments to that position. Rush's nominations of Joseph Priestley, James Woodhouse and John Redman Coxe were readily accepted by the Board of Trustees (21). As a close friend and protegé of Rush, Penington might have been nominated. Unfortunately, no portrait or other likeness of Penington appears to have survived.

References and Notes

1. J. Penington, *Chemical and Economical Essays, Designed to Illustrate the Connection Between the Theory and Practice of Chemistry, and the Application of that Science to Some of the Arts and Manufactures of the United States of America*, J. James, Philadelphia, 1790. This book is briefly described in E. F. Smith, *Old Chemistries*, McGraw Hill, New York, 1927, p. 18.

2. J. Cutbush, *A System of Pyrotechny*, C. F. Cutbush, Philadelphia, 1825, p. 184.

3. Sections on chemistry were present in an American edition of the British work, W. Nicholson, *Introduction to Natural Philosophy*, 2 Vols., Dobson, Philadelphia, 1788. B. Rush, *Syllabus of a Course of Lectures on Chemistry*, (no pub., Philadelphia, 1770, 48 pp.; 2nd Ed., [1774], 40 pp.; 3rd Ed., 1783, 39 pp.) was a pocket-size pamphlet. Four short pamphlets on chemical topics also predated Penington's *Essays*: B. Rush, *Several Methods of Making Salt-petre*, W. & T. Bradford, Philadelphia, 1775, 12 pp.; B. Rush, et al., *The Process for Extracting and Refining Salt-petre*, Bradford, Philadelphia, 1776, 8 pp.; [A. Lavoisier], *The Art of Manufacturing Alkaline Salts and Potashes*, [Philadelphia], [1785], 50 pp.; H. Moyes, *Heads of a Course of Lectures on the Philosophy of Chemistry and Natural History*, [1786], 15 pp. There were several printings of Moyes' *Heads* in the different cities he visited.

4. *Appleton's Cyclopedia of American Biography*, Vol. 4, Appleton, New York, 1887, p. 711. This reference also contains a biography of Penington's father and grandfather. The Penington family papers are in the Historical Society of Pennsylvania collections. The name of John's mother is from family notes in his journal, Reference 15.

5. G. Tselos and C. Wickey, *A Guide to the Archives and Manuscript Collections in the History of Chemistry*, The Center for the History of Chemistry, Philadelphia, 1987, p. 128.

6. Reference 1, p. 145 and 148.

7. J. Penington, *An Inaugural Dissertation, on the Phoenomena, Causes and Effects of Fermentation*, J. James, Philadelphia, 1790, p. 24.

8. Reference 1, dedication page.

9. J. Cutbush, *Philadelphia Weekly Aurora*, **1816**, *6 (6 February)*, 413-414. This entire article, on the history of American chemistry up to 1816, is reproduced in W. Miles, "Early American Chemical Societies," *Chymia*, **1950**, *3*, 95-113.

10. J. Penington, *Columbian Magazine*, **1789**, *3*, 459-464, 525-531, 577-582, 643-646, 693-695.

11. Penington's *Essays* was reviewed in *Columbian Magazine*, **1791**, *5*, 108-110, 179-183.

12. T. Ewell, *Plain Discourses on the Laws and Properties of Matter: Containing the Elements or Principles of Modern Chemistry*, Brisban & Brannan, New York, 1806, p. 8.

13. E. Rink, *Technical Americana. A Checklist of Technical Publications Printed before 1831*, Kraus International, Millwood, N.Y., 1981, p. 78.

14. Reference 7, p. 20. A review of Penington's dissertation appeared in *The Universal Asylum and Columbian Magazine*, **1790**, *IV, No. 6 (June)*, 377-378. It stated that this thesis was the "first in English" and described Penington: "though a young man, has acquired a considerable knowledge of chemistry. This seems to be his favorite science, and to it much of his time has been devoted."

15. J. Penington, *Common Diary from July 14, 1790 till Oct. 1 of the same year*. This unpaginated manuscript, located in the Library of the Historical Society of Pennsylvania, is in three parts and continues until 14 August 1791.

16. Reference 7, p. 22.

17. A.L.S., J. Penington to B. Rush, 3 August 1790. Library Company of Philadelphia.

18. *Gazette of the United States*, Wednesday, 3 July 1793. The entire announcement is reproduced in W. Miles, "Benjamin Rush, Chemist," *Chymia*, **1953**, *4*, 37-77. The Hopkins process, dated 1 July 1790 and signed by George Washington, was the first patent issued in the United States. See H. M. Paynter, "The First U.S. Patent", *Amer. Heritage Invent. Techn.*, **1990**, *6(2)*, 18-22.

19. L. H. Butterfield, *Letters of Benjamin Rush*, American Philosophical Society, Vol. 2, Princeton, 1951, pp. 672, 698.

20. *The Federal Gazette*, **1793**, *(20 September)*. Quoted in Miles, reference 18.

21. W. Miles, reference 18, pp. 72-75.

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CHEMICAL ARTIFACTS

The Apparatus Museum at Transylvania University

George M. Bodner, Purdue University

In March, 1775, Colonel Richard Henderson purchased 20 million acres from the Cherokees in an unsettled region of the British colony of Virginia then known as "Kan-tuck-ee" and hired Daniel Boone to mark a permanent trail into this territory (1). In May of the same year, the legislature that was assembled to organize a government for the new country voted to name it "Transylvania" (literally: across the woods), perhaps because the Romans had used this name to describe a region of eastern Europe that also lay beyond a great forest (2).

When news of this purchase reached the Virginia assembly, it was declared illegal because this body had reserved the right to extinguish Indian title to lands within its borders. Between 1775 and 1800, however, 150,000 people crossed through the Cumberland Gap and traveled down Boone's Wilderness Road into the region that the Virginia assembly eventually established as "Kentuckee county".

Dr. Robert Peter

One of the problems colonists faced was that of preserving their British cultural heritage. To do this, they turned to the schools (3). This might explain why the Virginia assembly took time in May, 1780 - during a period when their highest priority was the threat of British invasion following the fall of Charleston - to charter the establishment of Transylvania Seminary, which would serve as a spearhead of learning in the wilderness (1). Transylvania thereby became the 16th college established in the United States and the first established west of the Allegheny Mountains.

In 1789, the school was moved to Lexington, the commercial center of the region, and on 22 December 1798, it was merged with the Kentucky Academy to form Transylvania University. At their first meeting, the board of trustees of the new university established several colleges, including a Medical Department staffed by Doctor Samuel Brown, Professor of Chemistry, Anatomy, and Surgery, and Doctor Frederick Ridgely, Professor of Materia Medica, Midwifery, and Practice of Physic.

In 1799, Professor Brown was authorized to use $500 to import books and other items for instruction in the Medical College. Another $800 was allocated in 1805 for the purchase of apparatus for teaching natural philosophy, which included chemical apparatus and a galvanic battery. The Board of Trustees, in a public announcement that fall, proudly proclaimed the arrival of this apparatus, as well as additions to the college library, which now totaled some 1300 volumes.

In 1816, the trustees made an offer to Dr. Thomas Cooper to become the first professor of chemistry. The salary, however, was purposefully set so low that he would refuse the offer, which he did. In 1818, Professor Charles Caldwell arrived from the Medical School at the University of Pennsylvania.

Two years later, Caldwell convinced the legislature to give him $5000 for the purchase of books and apparatus for the Medical Department. At the same time, the city of Lexington loaned another $6000 to the college for the same purpose and an additional $2000 was raised from physicians throughout the South. In 1821, Caldwell went to Europe to purchase books and apparatus that formed the core of one of the finest medical libraries in the country. Caldwell wrote (4):

> ... the time of my arrival in Paris was uncommonly and unexpectedly propitious to that purpose ... Toward the close of that catastrophe (the French Revolution) the libraries of many wealthy and literary persons ... had ultimately found their way onto the shelves of the booksellers. ... I was appraised of the ... very precious repositories ... and purchased, at reduced prices, no inconsiderable number of the choicest works of the fathers of medicine from Hippocrates down to the revival of letters - works which in no other way, and perhaps at no other time could have been collected so readily and certainly, and on terms so favorable ... Hence the marked superiority of the Lexington Library, in those works, to any other ... in the whole United States.

In 1832, Doctor Robert Peter came to Lexington to help run The Kentucky Female Eclectic Institute. He soon became an adjunct professor at Transylvania and in 1838 was elected to the chair of chemistry at that institution. In 1839, he and Doctor James Bush spent most of the summer in London and Paris purchasing books and apparatus for instruction in the Medical Department. In his correspondence, Peter wrote (5):

> We have bought a great many fine books and a great deal of excellent apparatus and anatomical and other models. Transylvania will shine. No other institution in our part of the world will be able to compare with her in the means of instruction. In fact, I have seen none in Europe that is more completely prepared to teach *modern* medicine.

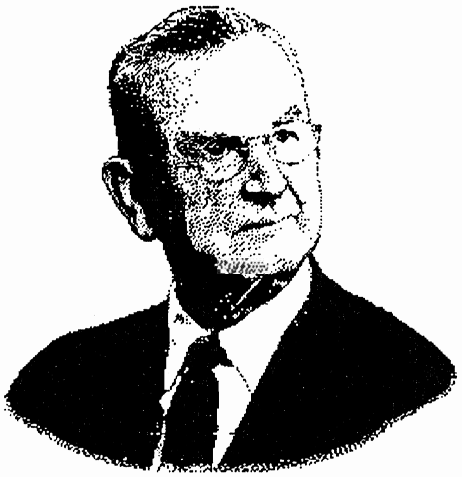
As a result of these purchases, in 1841 the Transylvania Medical Department was described as the "best endowed medical school in America" (1). Between 1817 and 1859, 6456 students enrolled in the Medical Department at Transylvania and the degree of Doctor of Medicine was conferred on 1881 of them. Transylvania thereby provided the foundation for the practice of medicine throughout much of the South. The Medical College was closed in 1859 as a result of a combination of political, social and economic forces as students and faculty drifted to other institutions in cities that had grown larger than Lexington.

The third major source of apparatus for the school was the purchase of the Philip S. Fall collection in 1857. Dr. Fall was the founder of the Eclectic Institute mentioned previously, for which the apparatus had originally been purchased.

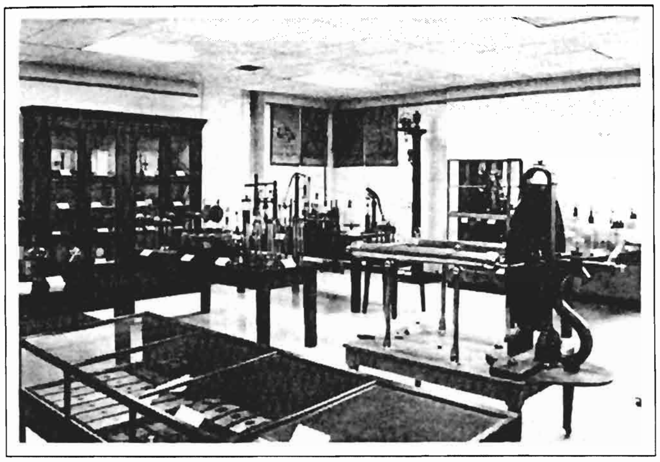
A significant fraction of the apparatus purchased for use in the Medical Department can still be found in the Museum of Early Philosophical Apparatus in Old Morrison Hall on the Transylvania University campus at 201 W. 3rd Street in Lexington. A few of Caldwell's purchases have survived, including a vacuum pump and an Atwood's Machine purchased from Pixii in Paris and a portable Sassure hygrometer. Most of the collection, however, traces back to Doctor Peter's visit to Europe in 1839 and Doctor Fall's purchases for the Eclectic Institute.

The collection, as it now stands, is a tribute to the efforts of Professor Leland Brown, who died on 30 August 1989 at the age of 91. Brown joined the faculty in 1932 as a professor of biology, was acting president from 1942 to 1945, and retired in 1965 as vice president for academic affairs. As early as 1910, part of the collection was stored in a museum, but the majority was either in use or stored in various departmental basements and storage shelves. The preservation of the collection became especially uncertain in 1933, when the museum was dismantled and stored in an attic.

Over a period of years, beginning in 1949, Professor Brown cleaned, assembled, and identified the apparatus - when possible - and prepared it for display in its permanent home. In 1959, a catalog describing the collection was published (6), copies of which can be obtained by contacting Professor Monroe Moosnick at Transylvania University or Carolyn Palmgreen, curator of the library special collection at Transylvania. A few items described in that catalog are missing: the Watkins and Hill balance, the blowpipe and double bellows, the camera lucida, the Daniell's hygrometer, the electromagnetic machine, the pith-ball electrometer, the eolipile or Newton's engine, the goniometer, the Hope's apparatus for measuring the density of water at different temperatures, the Marcet's steam apparatus for showing the relationship between pressure and temperature, and the safety lamp developed by Davy. In spite of these losses, the collection is both extensive and in excellent condition.



Dr. Leland Brown



A general view of the museum

The collection includes a variety of items of chemical interest, including a balance purchased from Charles Chevalier; a voltaic pile 23.5" tall and 3" wide that contains 58 separate metal disks; an eudiometer designed by Robert Hare of the University of Pennsylvania; an eudiometer designed by Volta; a large (10-qt. capacity) copper still; a small (1-qt. capacity) copper still; two large, three-neck Woulfe bottles, 5.5-6.5" in diameter and 8.5-12" tall; three small, two-neck Woulfe bottles, 3.5" in diameter and 6.5" tall; two tubulated retorts, 3" wide, 4.25" tall, with a 13" neck; one untubulated retort, 6" wide, 8" tall, with a 20" neck; a precipitation glass about 6" tall on a solid glass base that tapers from a 4" width at the mouth to 1.25" at the bottom; a 1-pt. capacity apothecaries' vessel calibrated with both 1 oz. and 1/4 pt. gradations; a demonstration cylinder 2" wide and 10.5" tall with a ground surface at the top; a 500 cc graduated cylinder with 5 cc gradations; a 100 cc graduated cylinder with 1 cc gradations; a 1000 cc gas collection bottle with 10 cc gradations; three lime-glass 1-L volumetric flasks, one of which is calibrated at 1000 cc; 12 assorted bell jars, 4-8.5" diameter and 7-14" tall; three receivers to be used with vacuum pumps, each equipped with two barometer tubes; and two tapered flasks, 3" diameter and 6.5" tall that can be sealed by inserting a glass sphere into the narrow mouth.

One of the more intriguing items of chemical interest is a "2nd edition" of an "Improved Scale of Chemical Equivalents", or chemical slide rule, which was constructed by Lewis C. Beck and Joseph Henry and manufactured in Albany in 1828. This chemical equivalents scale contains the following inscription:

> The Scale of Chemical Equivalents, the invention of which is due to Dr. Wollaston ... to facilitate the general study and practice of Chemistry. The present scale differs from the original one, in the assumption of Hydrogen, as ... unity ...

Under the heading "Mathematical Construction," the inscription goes on to state:

> It will be observed that the slider of the scale is graduated into divisions and sub-divisions continually ... in length, from 8 at the top to 330 near the bottom. These divisions correspond in relative lengths to the differences of the logarythms [sic] of the numbers placed opposite them.

It then goes into a protracted discussion of the mathematics of "logarythms" and notes that the distance between any two numbers on the scale is equal to the distance between any other pair that give the same ratio.

Under the heading "Chemical Explanation", the inscription states:

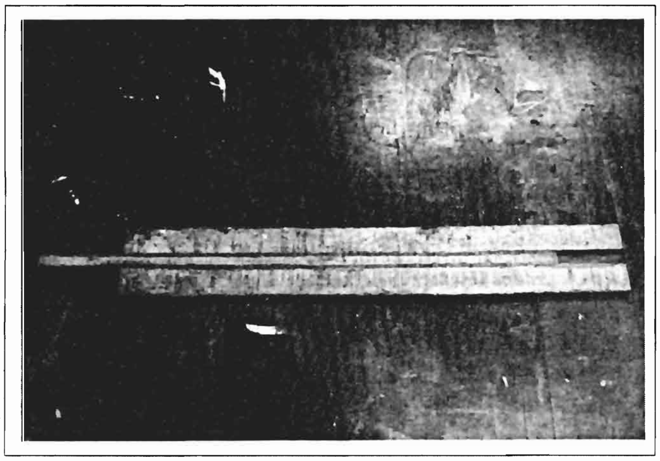
> The application of the logametric scale to Chemistry is founded on the most important fact in this science; which is, *that all bodies whether simple or compound that enter into Chemical combination, always unite in weights or in multiples of weights that have the same constant ratio to each other.* And as these relative weights have the same effect in forming neutral compounds and in producing other chemical changes they are called chemical equivalents, and may be expressed in numbers referable to a common standard taken as unity*. (*These have also been called atomic weights, because philosophers have supposed that in all cases of chemical combination an union takes place between the ultimate atoms of bodies. This is the basis of the Atomic Theory.) On this scale the least combining quantity of hydrogen is taken as the unit; and as eight times as much oxygen by weight enters into combination with hydrogen to form the chemical compound water, oxygen will be expressed by 8, and water by 9. If, therefore, the slider be so placed that 8 near the top of it coincides with the upper oxygen, the whole scale becomes a synoptical table of these chemical equivalents, having hydrogen as its radix. Thus 16 for the equivalent for Sulphur, 17 for Ammonia, 24 for Sodium, 70 for

A selection of the chemical apparatus, including Woulfe bottles, gas-generating bottles, flasks, retorts and a precipitation glass

Barium, 110 for Silver, &c. &c. ... In order to diminish the length of the scale ... it commences with oxygen at 8, instead of Hydrogen 1, and 10 atoms of hydrogen are placed opposite 10 on the slider. For the same reason, 2 carbon, the atomic weight of one atom of which is 6, is placed opposite 12. Again, as water and oxygen enter into combination in several definite proportions, 2 oxygen is placed opposite 16; 2 water opposite 18; 3 ox. opposite 24; 3 water opposite 27, &c. &c.

A series of "Examples and Illustrations" are then presented (In some cases, for greater clarity, I have inserted modern formulas or equations in square brackets):

1. Without moving the slider, the scale shows us that 50 is the equivalent number for carbonate of lime [$CaCO_3$]; this substance consisting of carbonic acid [CO_2 not H_2CO_3] and lime [CaO], we find the equivalent of the former to be 22, and of the latter 28 = 50. Any denomination may be given these numbers, as ounces, grains, parts, &c. But if we wish to ascertain the constituents of any number of ounces, grains, or parts, as 100 for example, we have only to place 100 on the slider at carbonate of lime; and carbonic acid is then opposite 44, and lime 56; which are the proportions of these ingredients in 100.



The Henry-Beck chemical slide rule

2. Suppose we wish to ascertain the constituents of 100 parts of nitrate of ammonia. Move the slider so that 100 is at nitrate of ammonia, which we find has 1. *W.* before it, indicating one proportional of water. Then 1. water on the scale is opposite 11.3, on the slider; ammonia opposite to 21.2, and dry nitric acid to 67.5. The constituents of 100 parts of nitrate of ammonia are, therefore, 11.3, water; 21.2, ammonia; and 67.5 dry nitric acid, = 100.

3. When oxygen at the top is at 8 on the slider, sulphate of potash [K_2SO_4] is at 88, which is therefore its equivalent number. In order to decompose this, we may take nitrate of barytes [$Ba(NO_3)_2$], the barytes having a greater affinity for sulphuric acid, than the potash. [$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$] The quantity requisite for the decomposition is 132, being the number at nitrate of barytes; and the amount of sulphate of barytes resulting from this decomposition will be 118. We can also ascertain the quantity of nitrate of barytes necessary to decompose 50, 100, 150 or any other number of parts or grains of sulphate of potash, by placing either of the above numbers on the slider opposite to sulphate of potash and then finding the number of nitrate of barytes.

4. To find the composition of the metallic salts, we ascertain the amount of acid and *oxide* of the metal. Thus nitrate of silver is equivalent to 172, and consists of dry nitric acid, 54, and oxide of silver, 118, = 172. So also we find 100 parts of sulphate of barytes to consist of dry sulphuric acid, 34, and baryta or oxide of barium, 66. And in all cases where *W* is not prefixed to the salt it is then supposed to consist of a base united to a dry acid.

As might be expected, the scale gives good results for predictions that can be confirmed experimentally, such as the weight of $BaSO_4$ produced from given weights of $Ba(NO_3)_2$ and K_2SO_4 or the weight of $AgNO_3$ that can be produced from a given weight of Ag_2O.

Faraday described the scale as follows (7):

> There is a small instrument, the invention of Dr. Wollaston, which though not directly concerned in the actual performance of chemical operations, is of great and constant use in the laboratory, either in supplying the information requisite previous to an experiment, or afterwards in interpreting and extending its results...

The scale only fails when applied to theoretical questions based on inaccurate or inappropriate theories. Within the limits of experimental error, for example, it correctly calculates the percent by weight of NH_3 in NH_4NO_3. It errs, however, when nitric acid is assumed to contain one equivalent of water mixed with "dry nitric acid" and the percent by weight of water and dry nitric acid in ammonium nitrate is calculated.

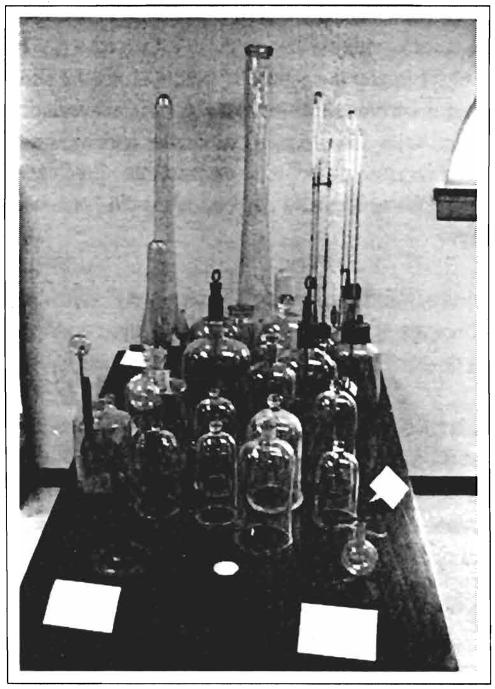
An impressive collection of apparatus purchased to demonstrate the basic laws of physics can also be found in the Transylvania Museum. This apparatus can be divided into two categories: mechanical and electrical. Some of the items in the first category include an Archimedes screw; an Atwood's machine; a black glass or landscape mirror; an apparatus for demonstrating collisions between bodies; a set of equilibrium tubes to show that water will fill interconnecting tubes of any size or shape to the same level; water and mercury fountains to be used with vacuum pumps; a set of friction blocks; glass models to demonstrate crystallographic forms; a heat conduction apparatus; three sets of heat reflectors; a heliostat, a hydrometric balance manufactured by Chevalier; a hydrostatic paradox apparatus; a set of Magdeburg spheres; an Oersted's apparatus for measuring the compressibility of liquids; a planetarium; a planetary path model to demonstrate Kepler's laws; a set of glass prisms on brass stands; a variety of vacuum pumps manufactured by Chevalier, including one that stands over 5' tall and is 3' wide that was originally purchased by Dr.

Fall for $1070; a horizontal pyrometer; a sextant and a quadrant; a 5'4" aperture, achromatic refracting telescope; a thermoscope of Rumford or differential thermometer; a Wedgwood's pyrometer; and an apparatus to show Newton's rings.

Electrical apparatus includes an aurora tube; a condenser of Aepinus; several electric batteries consisting of sets of Leyden jars; a cannon that could be fired with an electric spark; several electric machines for generating static electricity; including one in excellent condition that uses a 33" diameter glass plate; an electroscope; several glass piercers that could be used to pierce a card with the discharge from a Leyden jar; a Kinnersley thermometer to show the expansion of air when an electric spark is passed through it; induction cylinders for storing electric charge; a revolving armature engine; a revolving bar magnet; a sparking column and flyer for demonstrating the passage of an electric charge; several thunder houses to demonstrate the use of lightening rods to protect buildings; a series of electric discharge tubes with adjustable spark gaps that could be filled with different gases; an electrophorus and a Zamboni's apparatus purchased by Dr. Peter from Deleuil in 1839.

One item of physical apparatus of historical interest is a camera allegedly purchased by Dr. Peter during his visit to Paris in 1839, the year Daguerre introduced his photographic process. This camera has often been described as the source of the first Daguerreotype taken in Kentucky (8) and what may have been the first medical photograph (4). Brown (6) rejects the notion that this is one of Daguerre's cameras and identifies it as a Fox-Talbot camera - or an early copy of one - similar to one on display in London dated 1835. The curator of the photographic archives in the special collection at the University of Kentucky has presented cogent arguments suggesting that the camera was not purchased in Paris in 1839, but constructed by or for Dr. Peter in Lexington (9).

Wright has noted that the procurement of corpses for dissection was a challenge for medical students, who often turned to midnight expeditions to graveyards or commercial resurrectionists (1). Thus, it is no surprise that a major fraction of the collection at Transylvania consists of models to teach anatomy, which includes a pair of artificial eyes to demonstrate near and far sightedness; life-sized wax models of an arm, the human head, and the colon; plaster models of pathological conditions; a set of fetal skeletons illustrating development month-by-month; numerous plaster models of various organs mounted in wooden frames; and papier-mâché models of pregnant uteri. The collection also contains a set of 40 canvasses painted by A. Chazel in Paris of medicinal plants in the Jardin des Plantes in Paris, which were purchased by Dr. Peter in 1839. Because Peter's visit to Europe coincided with the publication of Schwann's cell theory, he included among his purchases a number of microscopes, including both aquatic (Raspail's) microscopes and cal-oxyhydrogen projection microscopes equipped with numerous slides of zoological and botanical specimens. It should be noted that the original medical school library has also been preserved intact, including nearly 760 volumes on chemistry spanning the period 1790-1850 (10).



A selection of bell jars and receivers

In his catalog, Brown (6) comments on the problems he encountered in identifying apparatus in the collection. One item he could not identify was described as follows:

> Figure 87 represents a small (9 and 5/8 x 5 x 4 inches) well-made box which is divided into eight compartments. In each velvet-lined compartment there is a small belljar receiver. These receivers are not all precisely of the same shape. Their brass tops appear to be made to fit into some receptacle. They have no obvious musical tones when struck.

Considering the reaction I receive whenever I mention that I had the privilege of spending a month as a Distinguished Professor at Transylvania University, it is intriguing that one of the few items that Brown could not identify was a set of blood-letting cups.

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BOOK NOTES

Out of Thin Air: A History of Air Products and Chemicals, Inc., 1940-1990. Andrew J. Butrica with the assistance of Deborah G. Douglas, Praeger, New York, NY, 1990. 336 pp. Cloth (Typeset). $39.95.

Despite the significant role industrial gases have played in the development of the U.S. chemical industry, it's easy for historians to overlook them. Gases may be important, but they just don't seem glamorous. In this history of the Air Products and Chemicals Company, Andrew Butrica uses the company archives and interviews with many of the men involved to prove that there's more excitement in this story than one might suspect.

50 years ago, even industrial users that required large amounts of oxygen depended upon gas delivery in cylinders. Leonard Pool, who founded Air Products, planned to fill a market niche by building small, on-site oxygen generating plants. This proved to be a good idea in the long run, but it was difficult to get started. During much of its history, Air Products was at a severe disadvantage because it was competing with much larger, well-established companies, and it was perennially short of capital. Air Products was successful because its leadership combined a tenacious determination to make this idea work with the flexibility to take advantage of whatever opportunities the market offered.

The character of the company was established by its response to its initial disadvantages. Since the company had little money available for research and development, in some cases it would offer to provide a customer with new technology at a low price, then use the job as an opportunity to develop the expertise that it needed to compete. Butrica comments that Pool assumed that if he could sell a product, his engineers could build it. Fortunately Pool made sure that he hired engineers who were good enough to make his promises stick.

The list of the challenges the company faced is a summary of the changing uses of industrial gases in the past 50 years. Providing oxygen for high altitude aviation in World War II, supplying oxygen for the steel industry, liquid oxygen and liquid hydrogen for NASA, and liquid nitrogen for a variety of applications (including quick freezing of McDonald's hamburgers) are only some of the applications that contributed to the growth of Air Products.

As it grew, the company diversified, sometimes into new areas that complemented the basic business, and sometimes into areas - like agricultural chemicals or welding gases - that were less successful. Two of these initiatives have become permanent divisions of the company (specialty chemicals and environmental/energy services) but industrial gases are still the main business. Despite the growth in size, the company continues to show a willingness to take calculated risks, sometimes with poor results, such as synfuels development, but more often leading to profitable new directions.

Writing an authorized company history can place a historian in the uncomfortable position of choosing either to describe setbacks and adverse decisions frankly or else keep the sponsor happy. Butrica seems to have done a good job of balancing these considerations. He presents the special difficulties of Air Products, such as labor disputes, research policies, and unsuccessful expansion, in a concise and diplomatic way. It's perhaps inevitable that the company founder, Leonard Pool, receives special and extensive consideration, but it would have been equally interesting to know more about the personalities and contributions of others who played key roles in the establishment of the company, such as George Pool, Ed Donley, and Dexter Baker.

In this book, Andrew Butrica not only restores industrial gases to their rightful place in the story of the chemical industry but also provides a fine 50th anniversary commemoration of a company that played a major role in that development. *Harry E. Pence, Chemistry Department, SUNY-Oneonta, Oneonta, NY 13820*

Physical Chemistry from Ostwald to Pauling: the Making of a Science in America. John W. Servos, Princeton University Press, Princeton, NJ, 1990. xxii + 402 pp. Cloth (Typeset). $49.50.

This superb monograph by John Servos delivers both more and less than its title might indicate. More in that it encompasses parallel biographies of Arthur Amos Noyes at MIT and Cal Tech and of Wilder Dwight Bancroft at Cornell. Neither was a scientist of the highest rank but both made unique contributions to the development of American physical chemistry: Noyes in fostering the careers of G. N. Lewis and Linus Pauling; Bancroft in founding and fostering the *Journal of Physical Chemistry*. Less in that this twin focus leads to the neglect of physical chemistry at Harvard, Johns Hopkins, Wisconsin, Chicago and elsewhere, to say nothing of developments in Europe. The author largely disarms the latter criticism:

> A few words must be said about what some readers may find to be a disturbing emphasis on the history of this discipline in America. Physical chemistry as a network of ideas is not American any more than it is German or French. And if this were a work of straightforward intellectual history, my concentration on American institutions and scientists would be unforgivable. But disciplines are more than disembodied ideas. They find leaders who are imbued not only with the norms of science but with the values of national cultures.

In spite of this disclaimer Chapter 1, "Modern Chemistry is in Need of Reform", provides an excellent summary of how Arrhenius, Ostwald, and van't Hoff drew together the various strands of chemical theory into the synoptic fabric of physical chemistry, an achievement culminating in the founding of the *Zeitschrift für physikalische Chemie* in 1887. Chapter 2, "Physical Chemistry from Europe to America", documents the impact that Ostwald had on the founders of American physical chemistry - Noyes (1888), Bancroft (1890), Kahlenberg (1893), Richards (1895), and Lewis (1900) all studied in Leipzig. Chapter 3, "King Arthur's Court: Arthur A. Noyes and the Research Laboratory of Physical Chemistry [at MIT]" recounts the remarkable achievement of A. A. Noyes in establishing the first school of American physical chemistry in the not entirely sympathetic environment of Boston Tech. Chapter 4, "The Phase Ruler: Wilder D. Bancroft and His Agenda for Physical Chemistry" describes Bancroft's forlorn attempt to establish Gibbs' phase rule as the guiding light of 20th century physical chemistry. Chapter 5, "Physical Chemistry in the 'New World of Science'" is the least satisfactory in the book; indeed it prompts my only substantial criticism. As is common with history of science monographs, several of the chapters have appeared "in different form, elsewhere". This leads to certain "the-story-so-far" lead-ins and parts of Chapter 5 seem to interrupt the fine narrative flow of the rest of the book. The story line resumes with Chapter 6, "From Physical Chemistry to Chemical Physics" and concludes with the rather sad Chapter 7, "A Dissenter's Decline". Bancroft, however, went down fighting. In 1931, in a strange article "How to Ripen Time", a reference that seems to be missing from this generously, even obsessively, documented book, Bancroft wrote somewhat unfairly of the "victor" G. N. Lewis:

> G. N. Lewis, now of the University of California, introduced the activity concept to meet the difficulty. We can always make the experimental data agree with the theoretical values by multiplying the data by the ratios of the theoretical values to the experimental values. Of course it was not done as crudely as that. The multiplying ratio was called the activity coefficient ... We might consider Mrs. Eddy and G. N. Lewis as the Gold Dust Twins of Christian and Physical Science. Mrs. Eddy eliminates sickness but admits error. Lewis admits sickness but eliminates error.

Servos writes well and he has a good ear and eye for the felicitous phrase:

> Few schools commanded resources as rich as California's, and none had a talent greater than Lewis's, but a rising tide raises all ships.

or on Gibbs' belated recognition:

> There is, however, a difference between being honored and being understood.

Lewis' urbane response, as General Pershing's scientific advisor, to repeated requests for the provision of gas masks for carrier pigeons is left for discerning readers to discover for themselves.

There are few monographs in the history of science that can be recommended unreservedly to practicing chemists. This book is one of the few. *Derek A. Davenport, Department of Chemistry, Purdue University, West Lafayette, IN 47907*

Linus Pauling: A Man and his Science. Anthony Serafini, Paragon House, New York, NY, 1989. xxii + 310 pp. Cloth (Typeset). $29.98.

Should the *National Enquirer* ever launch a scientific book club, Anthony Serafini's *Linus Pauling: A Man and His Science* would make an appropriate first selection. The second sentence of the Introduction sets the tone: "... he [Pauling] could well be called the American Cowboy of science". A few pages later we find: "Born into conflict and combat with the rawest elements of nature, poverty, and disease, he toughened himself for a life-time of struggle". Later chapters deal with "The McCarthy Era and the 'Race' for DNA", "On the Trail of a Cure for Mental Illness", "A Brush with Death", "At War with Herman J. Muller", "Squaring Off with William F. Buckley, Jr.", and "Pauling *vs.* the Medical Establishment". Under the circumstances it's a marvel the man has lived long enough to write *How to Live Longer and Feel Better*.

While Linus Pauling has been a public figure, even a *de jure* public figure, for close to 50 years, and though his non-scientific activities are all of a piece with his scientific ones (indeed he would probably dispute such nice distinctions), it is for his remarkably varied scientific achievements that he will be chiefly remembered. The names of crusaders rarely outlast the crusade. And it is with Pauling's scientific work that our author is least happy:

> The parameters physicists use to "describe" electrons are called "quantum numbers" (a sort of measuring unit, used in much the same way that carpenters talk about lumber in terms of board feet).

As a consequence, Serafini shortchanges the seminal scientist in favor of the public figure. *The Fairfield Chronicle* is cited but not the *Journal of the American Chemical Society*. While he makes much of Pauling's vaulting imagination, he often does so at the putative expense of "competent, hard-working, ruthlessly accurate and technically correct" scientists such as John Slater. The repeated denigration of Slater does an injustice to a first-rank physicist and an outstanding teacher of several generations of physicists. Even less admirable is Serafini's tendency to make serious and snide assertions only to back away from them a few sentences later:

> Bragg was bristling ... about Pauling's thievery and lack of professional ethics ... Many people who have examined Pauling's early career believe that Pauling really did steal his famed principles from Bragg.

Who are these 'many people'? The chapter notes are silent.

> However, numerous scientists at Caltech ... seemed to believe he [Pauling] had actually written part of *The Structure of Line Spectra*.

Who are they? Where is the evidence that he did not? Pauling's and Goudsmit's names appear equally on the title page. Both were Associate Professors at their respective institutions, each no doubt eager for fame, if not fortune. Could Goudsmit have been so self-effacing as not to insist on an acknowledgment that Pauling was merely the translator? And why did he keep the charming photograph of Pauling and his son Peter reproduced in the book? Similar examples of journalistic sensationalism occur throughout, largely at the expense of any remotely adequate treatment of Pauling's remarkable scientific and teaching career. Potential readers would do well to check John Roberts' cautionary and caustic review [*Chemical and Engineering News*, 29 January 1990].

Is there nothing good to be said about this lopsided and shabby book? Since memories are short and Pauling's life happily long, it is salutary for chemists (and others) to be reminded of the astonishing range of Pauling's activities. No 20th-century scientist, not even the sainted Einstein, has assumed such an active public role, though under intimidatingly different circumstances Andrei Sakharov may have come close. A satisfactory "Life and Times of Linus Pauling" has yet to appear, though Robert Paradowski's work-in-progress augurs well. Perhaps the man himself could be persuaded to find time in his busy schedule to treat us to his own account. For in spite of Serafini's surly "writing is not Pauling's forte", he has a fine ear for language, a gift for narrative and a splendid sense of drama. Such an autobiography would be well worth waiting for. *Derek A. Davenport, Purdue University, West Lafayette, IN 47907*

Schwazer Bergbuch. Erich Egg (Editor), Akademische Druck- und Verlagsanstalt, Graz, Austria, and Verlag Glückauf GmbH, Essen, Germany, 1988. 53 + 396 pp. Cloth (Typeset and Photoreproduction). 780 DM.

This book on mining dates back to the year 1556. It has never been printed before, though ten hand-written manuscripts are known to exist in various locations in Austria and Germany: three in the Tirol Provincial Museum in Innsbruck; and one each in the Austrian National Library, Vienna; the Mining University, Leoben; the Salzburg Provincial Archives, Salzburg; the Mining Museum, Bochum; the Bavarian National Library, Munich; the German Museum, Munich; and in Werthein Parish. The importance of this document lies in the fact that it was made available in a hand-written form in the same year as Agricola's book, *De re metallica*, was published and that it surpasses Agricola's book in its drawings, which are brilliantly colored and of extreme beauty.

The book is written in Old German and its title, *Schwazer Bergbuch*, translates as "the Mining Book of Schwaz". In the Middle Ages, Schwaz was the second most important town in Austria after Vienna, the capital. Schwaz today is a small village in Tirol, 35 kilometers east of Innsbruck. The author of the book is unknown, but an artist by the name Ludwig Lassl signed the drawings.

The book was written during the age of Reformation, a period not only of great geographical discoveries and artistic movements, but also an age of great merchants. Two families dominated European commerce and banking: the Fuggers in Germany and the Medici in Italy. Both families made their fortune in textiles and then turned to banking: the Fuggers at Augsburg and the Medici at Florence. The Fuggers made many loans, especially to kings and princes, in return for which they got control of many enterprises. Among these were mines in Hungary, Germany, southern Spain, and the one in Schwaz.

Rich silver-copper ore containing 35-41% Cu and 0.3-0.8% Ag was discovered in Schwaz in 1410 and in the period 1470-1530 it became the largest copper and silver producer in Central Europe. In the 1550's, however, mining costs began to increase because of the necessity of having to go deeper underground and the resulting increase in problems due to ground water. Added to this was a decline in the quality of the ore being mined.

Only three pages of the book are devoted to the technical aspects of ore treatment. The rest of the book is devoted to the people operating the mine - about 20,000 working in about 300 galleries. Each job is described and illustrated, including methods of supplying food, clothes, tools, etc., and management of the work place. The book contains a translation of the medieval German of the text into modern German by Dr. Ing. Heinrich Winkelmann, the former director of the Mining Museum in Bochum. The supplementary, 53-page volume, "Schwazer Bergbuch Commentarium", by Erich Egg, the former Director of the Tiroler Landesmuseum Ferdinandeum in Innsbruck, gives valuable comments on the book and its history. It is thought that the book was written as a document for a mining conference called the "Synode" that was held in Schwaz in 1557. Previous conferences were held in 1494, 1496, 1498, 1500, 1501, 1507, 1510, 1512, and 1513.

The book contains 100 colored drawings and is available in two different bindings: the standard edition (facsimile and commentaries bound together) at a price of 780 DM, or the facsimile volume in leather binding (with the commentary volume in a separate half leather binding) at 1,560 DM. Both editions are gold decorated. The book is certainly a welcome addition to the mining library. *Fathi Habashi, Department of Mining and Metallurgy, Laval University, Quebec City, Canada G1K*

The Right Place at the Right Time, John D. Roberts; *From Cologne to Chapel Hill,* Ernest L. Eliel; *From Design to Discovery,* Donald J. Cram, American Chemical Society, Washington D.C., 1990. xix + 299 pp; xxi + 138 pp; xxi + 146 pp. Cloth (Typeset). $24.95 each.

These three volumes are the first of a projected 22-volume series edited by Jeffrey I. Seeman of the Philip Morris Research Center. Originally solicited as chapters for a single book intended to document the development of contemporary organic chemistry, the length of the contributions soon caused the project to mushroom into the present series. Seeman not only conceived the original project but also obtained corporate funding to help subsidize the final version. On all counts he is to be commended, as he has not only single-handedly doubled the number of known chemical autobiographies, but has provided future historians of organic chemistry with a veritable treasure trove.

As for the autobiographies themselves, they are as variable as the authors. From the standpoint of human interest and anecdote, the most successful of the three under review is doubtlessly the volume by John Roberts, with Eliel's contribution not far behind. The least successful is the volume by Cram, who, after confessing to a middle-age angst of dwelling on the past, proceeds to write a review article on his current research (indeed one of my colleagues borrowed the book to use as a reference in writing a grant proposal).

What is most interesting, however, is what all three accounts have in common. All are written for chemists rather than for the general public and the reader is plunged into the details of the author's research with little or no preliminary preparation. Indeed, so focused are the accounts, that even non-organic chemists may find themselves a bit lost at times. This apparent inability to place one's work in a larger historical perspective, and even to spell out its ramifications for the structure of chemistry as a whole, is not, I suspect, a failing of the authors alone, but is typical of chemists in general. This view is reinforced by the fact that all three authors became involved in the conceptual issues which later made them famous as a result of much more limited experimental projects, chosen either because they were manageable in terms of the equipment and chemicals available at the time or because they were simple extrapolations of projects assigned them as students or postdocs. There are no tales of reading the great literature of chemistry, identifying key conceptual issues and explicitly setting out to resolve them. Rather these larger issues evolved gradually out of the more mundane and more limited experimental projects. This observation is not intended as a criticism of the authors, but rather to draw attention to the fact that they are telling us (albeit indirectly) something very important about the way chemistry is done - something of which philosophers of science, who continue to use theoretical physics as their model of the scientific method, should take note.

Finally, all three authors express a certain nostalgia for the excitement of the 1950's and 1960's which seems to have vanished in this decade of declining chemistry enrollments, dwindling research funding, and increasing emphasis on applied rather than fundamental research - a nostalgia best expressed in Roberts' title "The Right Place at the Right Time". *William B. Jensen, University of Cincinnati, Cincinnati, OH 45221.*

LETTERS

Kasimir Fajans

Today I received a copy of the Spring 1990 issue of the *Bulletin for the History of Chemistry*. This issue is particularly interesting to me for the second part of the biography of Professor Kasimir Fajans because I knew him since the 1920's when he was Professor at the University of Munich and I was a scientific research associate at the Kaiser-Wilhelm-Institut in Berlin-Dahlem. Evidently all the other articles in the issue of the *Bulletin* have been and, in fact, always are of great interest and satisfaction to me.

Herman Mark, University of Texas-Austin

The Hofmann Sodium Spoon

Two days after reading your interesting little end-piece on the Hofmann sodium spoon, I came across the following in Edward Frankland's *How to Teach Chemistry. Hints to Sci-*

ence Teachers and Students (London, 1872), pp. 7-8:

> Drive out hydrogen by an alkali metal. First illustrate by throwing a piece of potassium on the surface of some water; then collect hydrogen displaced by sodium, carefully guarding against explosions (fig. 6). The "sodium spoon", and use of wire gauze, unless quite new, is objectionable; it is safer to use short pieces of leaden tube, 1/4 in. diam., closed at one end and filled with sodium, lying in the pneumatic trough beneath an inverted gas-jar full of water ...

I don't quite understand the contraption mentioned by Frankland and, in any case, the item illustrated looks more like a thin toasting fork. No doubt Frankland aired his objections to the teachers in the original lectures, but the editor (Chaloner) takes it for granted that any science teacher reader will understand.

William H. Brock, Beckman Center for the History of Chemistry

A warning about the "sodium spoon". I had one that I resurrected from a 1930's lab drawer (literally untouched in an old high school), and I finally used it. Granted, I used a rather larger chunk of sodium - about half the size of the basket - but what happened could have happened with any size sample. A student did it and, in a word, I came the closest in my 30 years as a teacher to a disastrous accident. The explosion shattered a liter beaker, but (now I know that God watches over drunks, babies and chemists) the student was unharmed. He was a good athlete and dove to the floor.

Joseph D. Ciparick, New York City

I just got the Fall 1990 issue of the *Bulletin for the History of Chemistry* and thought you might be interested in the following: 1. We have one of the sodium spoons in our old apparatus here at Harding. It measures 29.6 cm long, with a 2.5 cm diameter basket. 2. The sodium holder is also in the 1906 catalog for the Arthur H. Thomas Company. 3. The 1893 catalog for the Emil Greiner company does not have the sodium holder, though it does carry other "Hofmann" apparatus.

William D. Williams, Harding University

Hydrogen Bonding

Congratulations on an especially fine issue of the *Bulletin*. The article on hydrogen bonding caught my eye first because I had a lecture course from Worth Rodebush as a first-year graduate student at Illinois. He was a terrible lecturer at that time. The only thing I have retained is his directions for pronouncing French: "Begin, and anytime you feel like stopping, stop."

Paul R. Jones, University of New Hampshire

I recently received issue seven of the *Bulletin* ... I enjoy each issue quite a bit. The hydrogen bonding article will be most helpful since I try and give my high schoolers as much historical flavor as I can.

John Park, Diamond Bar High School

EVENTS OF INTEREST

* DaCapo Press has reissued a paperback reprint of Douglas McKie's classic biography of Antoine Lavoisier for $14.95, and Dover Press has now released its cloth reprint of the Hoover translation of Agricola's *De re metallica* in a paperback edition for $17.95.

* Dr. O. Bertrand Ramsay delivered the Fourth Annual Oesper Lecture on the History of Chemistry on 8 March 1991 at the University of Cincinnati. The subject of the lecture was "The Role of the Use of Molecular Models in the Historical Development of the Theory of Molecular Structure". The lecture was followed by the opening of a new museum display entitled "The Evolution of Molecular Models from Dalton to Drieding". Most of the artifacts in the display are part of a collection of historically significant models assembled by Dr. Ramsay and recently donated to the Oesper Collection. For further information, contact Dr. William B. Jensen, Department of Chemistry, University of Cincinnati, Cincinnati, OH 45221, (513) 556-9308.

* The Beckman Center for the History of Chemistry plans to conduct the first of a series of annual workshops for high school chemistry teachers on the history of chemistry the week of 21-26 July 1991. Each workshop will focus on the history of one of the subjects normally taught in the high school chemistry course. Participants will hear lectures on the subject by guest lecturers, attempt to evaluate how the historical material might be adapted to classroom use, and participate in group projects directed at assembling a teaching resource packet. The topic of this year's workshop will be the history of the periodic table and atomic structure and the guest lecturer will be Dr. William B. Jensen of the University of Cincinnati. For further information contact the Beckman Center for the History of Chemistry, 3401 Walnut Street, Philadelphia, PA 19104-6228.

* The 1991 Annual Meeting of the History of Science Society will be held in Madison ,Wisconsin, on 31 October - 3 November 1991. The meeting will run concurrently with the Society for the History of Technology's annual meeting and the joint HSS-SHOT conference on Critical Problems and Research Frontiers in History of Science and Technology. The number of regular HSS sessions will be reduced somewhat because sessions of interest to HSS members will be incorporated into the other meetings. Proposals for sessions and individual papers are due on 1 April 1991. For guidelines on submitting

proposals, please contact the HSS program chairs, Albert Moyer and Richard Hirsh, Department of History, Virginia Tech, Blacksburg, VA 24061-0117. For information on SHOT sessions, contact Deborah Fitzgerald, 1225 Orchard Drive, Ames, IA 50010.

* The Division is pleased to announce that its most recent book, *Electrochemistry, Past and Present,* based on the symposium organized by John T. Stock and Mary V. Orna in Toronto has, because of demand, gone into a second printing!

* Dr. William H. Brock, current Edelstein International Fellow in the History of Chemical Sciences and Technology, is preparing a new history of chemistry, entitled *At the Sign of the Hexagon,* as part of a new history of science series to be published by Fontana Paperbacks. Dr. Brock has spent the last six months at the Beckman Center in Philadelphia and, the situation in the Middle East allowing, will spend the period from 1 March - 30 June at the Edelstein Center in Jerusalem.

* 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 October-December, and 1 November for 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, The Oesper Collection in the History of Chemistry, Department of Chemistry, ML 172, University of Cincinnati, Cincinnati, OH 45221.

FUTURE MEETINGS

Atlanta .... 14-19 April 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.

* *Michael Faraday - Chemist and Popular Lecturer* (Cosponsored by CHED). Contact Derek Davenport, Department of Chemistry, Purdue University, West Lafayette, IN 47907, (317) 494-5465.

* *History of Synthetic Fibers.* Contact R. B. Seymour, Department of Polymer Science, University of Southern Mississippi, Southern Station, Box 10076, Hattiesburg, MS, 39406, (601) 266-4868.

New York .... 25-30 August 1991

Five copies of 150-word abstract (original on ACS Abstract Form) by 15 May 1991. Title of paper by 1 May 1991.

* *General Papers.* Contact J. L. Sturchio (see address above).

* *History of Steroid Chemistry.* Contact L. Gortler, Department of Chemistry, Brooklyn College, Brooklyn, NY 11210, (718) 780-5746, or J. L. Sturchio.

* *A Century of Chemistry in New York (Commemorating the Local Section Centennial).* Contact J. Sharkey, Department of Chemistry, Pace University, Pace Plaza, New York, NY 10038, (212) 346-1710.

* *Chemistry and Crime III - Forensic Methods: Past, Present and Future.* Contact S. M. Gerber, Color Consultants, 70 Hillcrest Road, Martinsville, NJ 08836, (201) 356-4721; or R. Saferstein, New Jersey Forensic Laboratory, P.O. Box 7068, West Trenton, NJ 08825, (609) 882-2000, Ext. 2692.

* *Emil Fischer: One Hundred Years of Carbohydrate Chemistry* (Cosponsored by CARB).

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 (see address above).

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

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

Geneva .... 21-22 April 1992 (Tentative)

* *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 J. L. Sturchio (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 J. L. Sturchio (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 J. L. Sturchio (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.

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* *BCHOC Representative:* James J. Bohning, Beckman Center for the History of Chemistry, 3401 Walnut Street, Philadelphia, PA 19104-6228, (215) 898-1302.

CHEMICAL GENEALOGY UPDATE

A short reminder that the Division still plans to publish a bibliography of chemical genealogies to coincide with the Symposium on Chemical Genealogies at the 1992 San Francisco meeting. To date we have received the following:

* *Departmental Genealogies:* Alberta, Baylor, Brooklyn College, California State (Fresno), California State (Long Beach), Case Western, Cincinnati, Colorado State, Illinois (Urbana), Indiana, Juniata, Louisville, MacMaster, Michigan State, New Hampshire, North Carolina, North Texas State, Northwestern, Oklahoma (Norman), Purdue, Tennessee (Knoxville), Texas (Austin), Texas Christian, Vassar, Villanova, Wayne State, Wisconsin (Madison), Xavier.

* *Individual Genealogies:* Analytical Chemists, John Bailar and students, George Büchi, Joseph Bennett, Maurice Bursey, Ernest Campaigne, Philip Chenier, William Ehmann, H. J. Emeleus, N. Howell Furman and students, Peter Girardot, William Hagen, Clinton Hassell, Joseph Hirschfelder and students, Paul Kuroda, Izaak Kolthoff and students, Foil Miller, James Owens, Thomas Phipps, Malcolm Renfrew, Theodore Sakano, Harry Schultz, George Wahl, James Winefordner.

If you have a departmental or an individual chemical genealogy to share, please contact Dr. Paul R. Jones, Department of Chemistry, University of New Hampshire, Durham, NH 03824-3598, (603) 862-1550.

PARTING SHOTS

Of Beehives and Babo Generators: The Adventures of a Museum Curator

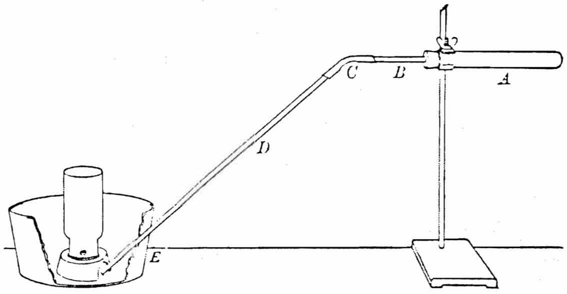
William B. Jensen, University of Cincinnati

According to the old proverb, "all things come to those who wait", though in the case of the Chemical Apparatus Museum at the University of Cincinnati, a more accurate rendition would be that "all things come to those who search long enough". A surprisingly small percentage of the artifacts in the museum have been acquired through unsolicited donations and an even smaller portion through direct purchase from antique dealers. The majority has come from directly visiting chemistry departments throughout the country and actively going through their stockrooms and basement storage areas. Once an historically interesting item is found, the department is usually more than willing to donate it to the museum, since the alternative is often the trash barrel.

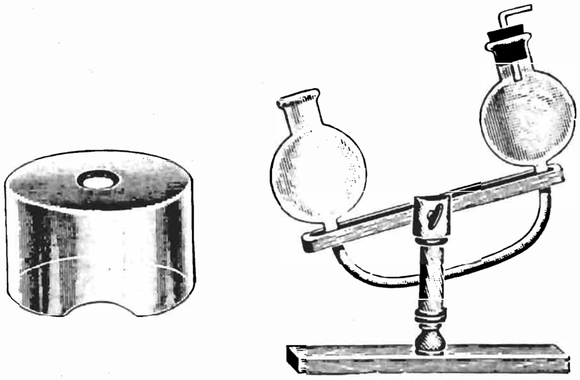
The occasion for these visits is normally an invitation to give a seminar on the history of chemistry and these, in turn, are often financed by the chemistry department at Cincinnati as part of its seminar program for graduate student recruitment. I mention this only because at times I vaguely wonder what impression my visits must make on perspective recruits. After all, if this guy travels the country begging for every piece of outdated, broken-down apparatus in sight, Cincinnati must be awfully hard up for equipment!

Given about an hour's worth of search time and a stockroom or a dimly lit basement storage area filled with hundreds of boxes, how does one decide which boxes to ignore and which to open? Generally I have found that the success rate is directly related to the ambiguity of the label on the box. Specific labels, such as "beakers", "bottles" and "distilling flasks", seldom yield anything unexpected, but adjectives such as "miscellaneous" or "assorted" and occasionally even "odd" or "old" quicken my pulse and have usually proven profitable.

The downside of this choice is that it can sometimes prove very difficult to identify just what it is that one has uncovered and I have at times come perilously close to ignoring objects which have later proved to be of interest because I did not immediately recognize what they were. Thus at DePauw University several years ago, while going through some boxes of antique equipment rescued from the old chemistry building by Dr. Donald Cook and tucked away in the basement of the new building, I uncovered a box of what appeared to be white porcelain dishes, each with a hole in the bottom and a groove cut in the lip. I also found a large number of small two-necked Woulfe bottles which, from the residues inside, had obviously been used as student hydrogen generators. Since I could not locate any pneumatic troughs to go with the generators, I surmised that the dishes might have something to do with the collection of the hydrogen and to be safe took a few for the museum.



A beehive stand in use



(Left): A glass beehive. This example lacks the characteristic beehive shape. (Right): A Babo generator

While reexamining the dishes in my hotel room that evening, I dimly recalled reading in a 19th century textbook that high school teachers on tight budgets could save money by making their own student pneumatic trough stands from small flower pots by cutting a groove in the lip with a file. Once back in Cincinnati, consultation of the apparatus catalogs in the Oesper Collection quickly revealed that the porcelain dishes were in fact the commercial equivalent of the flower pot stands - a type of pneumatic trough stand known, presumably because of its shape and the location of the openings, as a "beehive". Interestingly, though I have located textbook illustrations of the beehives I found at DePauw, the only examples I have uncovered in commerical apparatus catalogs are made of glass or zinc rather than porcelain.

A similar incident occurred more recently at Eastern Michigan University, where I was shown a display case containing a wonderful collection of old lime-glass apparatus rescued by Dr. Bert Ramsay. Among the items were two examples of an object which looked like two glass leveling bulbs fused to an interconnecting U-tube. These I immediately recognized as part of a gas-generating apparatus, though the wooden stands were missing and they were in the case upside down. Bert donated one of them to the museum and consultation of the catalogs quickly revealed that they were part of a solid-liquid gas generator known as a Babo generator, after its inventor, the 19th century German chemist, Clemens Heinrich Lambert von Babo (1818-1899). To operate, one bulb was packed with the solid reactant (e.g., iron (II) sulfide) and the other was filled with acid. When mounted on the missing wooden stand, the apparatus could be tilted in one direction to cover the solid reactant with acid or in the other direction to drain all of the acid into the second bulb. Intermediate tilt angles allowed one to vary the percentage of the solid in contact with the acid and so regulate the rate of gas evolution much more elegantly than in the more common Kipp generator. The 1914 catalog for the E. H. Sargent Company of Chicago lists Babo generators with a capacity of 1 liter, though it doesn't indicate whether this refers to one bulb or to both bulbs together (1). The generator found at Eastern Michigan, which is now mounted on a reproduction stand, has a capacity of only 250 mL (both bulbs) and was apparently intended for the use of only one or two students in a qualitative analysis laboratory.

Babo, by the way, was a prolific inventor of laboratory apparatus, including an ozone generator (2), a burner (3), an air bath (3), an absorption tube (1), a retort stand, a gas-oven, and an explosion oven (2). He is also credited with being the first to use the centrifuge in a chemical laboratory.

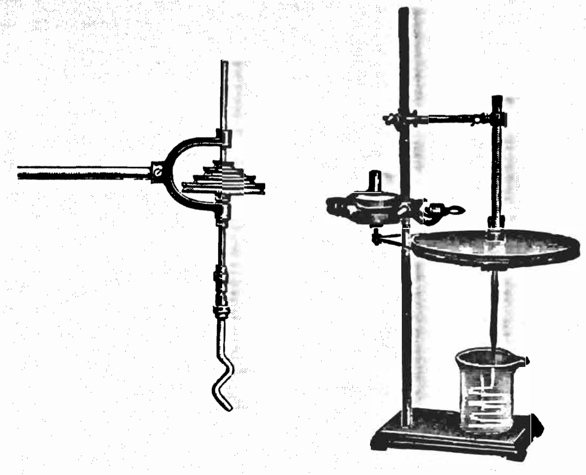
Even more satisfying is when one is able to assemble a complete piece of apparatus from parts collected from several sources over a long period of time. This December, for example, I found a clamp, with three wooden pulleys of increasing diameter mounted on it, in the basement of Macalester College. This proved to be the missing part to a water-driven laboratory stirrer and, when united with the cast-iron water motor found in the back room of the Ohio Mechanics' Institute in Cincinnati three years earlier, gave us a complete turn-of-the-century stirring apparatus, as well as elegantly illustrating the adage about all things coming to those who search long enough.

References and Notes

1. *Scientific Laboratory Apparatus, Catalog 20*, E. H. Sargent Co., Chicago, IL, 1914, pp. 176, 179, 290.

2. Anon., "Lambert Freiherr von Babo", *Berichte*, **1899**, *32*, 1163-1164.

3. R. Arendt, *Technik der anorganischen Experimentalchemie*, 4th ed., Voss, Leipzig, 1910, pp. 126, 307.



Turn-of-the-century laboratory stirrers. (Left): A stirrer with variable speed. (Right): A stirrer with the water motor attached.

COMING IN FUTURE ISSUES

- "The 1990 Dexter Address"
  by Colin Russell
- "The Rise and Decline of the British Dyestuffs Industry: An Object Lesson for American Industry"
  by Martin D. Saltzman and Alan L. Kessler
- "Thomas Ewell's Plain Discourses"
  by Robert H. Goldsmith
- "Chemical Industry in Colonial Virginia"
  by Will S. DeLoach
- "James Tytler's System of Chemistry"
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