Rediscovery of the Elements

Carl Wilhelm Scheele

James L. Marshall, *Beta Eta '71*, and
Virginia R. Marshall, *Beta Eta '03*
Department of Chemistry, University of North Texas, Denton TX 76203-5070,
jimm@unt.edu

Figure 2. Cities in which Scheele lived are underlined; they were all in Sweden, including Stralsund, which was then Swedish Pomerania.

Figure 3. "Scheele Haus," the birthplace (1742) of Scheele, is the center building, located at Fährstraße 23, Stralsund, Germany (N 54° 18.99; E 13° 05.56). This building is elegantly marked with a plaque and a small exhibit inside. The view is eastward, downhill toward the Baltic Sea only 200 meters away and from which cold winds often blow up the street. Occasional plaques in the city dating from the 1700s are engraved in Swedish, attesting to the fact that the region was part of Sweden at that time.

The Genius of Scheele. Few chemists can boast as astonishing a career as that of Carl Wilhelm Scheele (1742–1786). (Figure 1). Living only for 44 years, this Swedish pharmacist discovered more elements (seven) than any other scientist (Note 1)—all before the era of modern chemistry of Lavoisier's *Traité*.[1] In the confines of a cramped home laboratory, Scheele also discovered a score of fundamental organic compounds and gases including tartaric acid, lactic acid, oxalic acid, citric acid, malic acid, uric acid, casein, glycerol, hydrogen sulfide, hydrogen fluoride, and hydrogen cyanide.[2,3] He developed a procedure for processing phosphorus from bones, replacing the previous inefficient procedure involving urea.[2,3] He discovered the action of light on silver salts, laying the foundation for black-and-white photography;[4] distinguished plumbago (graphite) and molybdenite (MoS_2); and "above all"[3] discovered oxygen. With an amazing memory, he could read a book and thereafter use its contents without referring to it again.[5] His abilities and research so impressed the scientists of the Royal Academy of Sciences of Sweden that they elected him a member—although at that time (1775) he held merely the station of a pharmacist's apprentice. He declined an offer in 1777 to succeed Andreas Sigismund Margraff (1709–1782) as director of the Berlin Academy. Instead, shying from politics, he chose unpretentious surroundings so that he could work "without jealousy or malice" in his own pharmacy laboratory where his research could be done "without such hindrances."[2]

Figure 1. Statue of Scheele in Scheeleparken in Köping (N 59° 30.79; E 15° 59.47), which lies between Scheele's grave and the former site of his pharmacy. This statue was fashioned by Carl Milles, "the most famous Swedish sculptor" who has created many sculptures in prominent sites in Sweden. Inset: Medal struck by the Swedish Academy 3 years after Scheele's death. No authentic portrait of Scheele exists (Note 4).

Scheele the Pharmacist and Chemist. During his career Scheele lived in six different cities (Figure 2). He was born in Stralsund, Germany (Figure 3), at that time Swedish Pomerania. His parentage was German, and throughout his life he used this language to write down his laboratory notes. He received an excellent education and experienced an enjoyable childhood painting and collecting insects and plants. At home he was particularly fascinated with the conversations of the friends of his parents, who included doctors and pharmacists.

At the age of 14 Scheele moved to Göteborg (Figure 4) to replace his brother Johann Martin, who had been a pharmacist apprentice and who had died at the age of twenty. At this time, Göteborg was the center of economic prosperity, a showcase city embodying the wealth and power of Sweden. Here Scheele fell in love with the sumptuously provisioned stockroom of the pharmacy, and he is known to have experimented and studied 70 chemicals—every one on the shelves except indigo. From borrowed textbooks of chemistry and pharmacology he devoted himself to absorbing all possible knowledge on the subjects. He depended particularly on an old but famous textbook *Laboratorium Chymicum* (1716, posthumous) by Johann Kunckel (1630–1703), who, like Scheele, was a gifted and patient experimentalist.[6]

Figure 4. Göteborg (Gothenburg) was a prosperous city when Scheele was a pharmacy apprentice here (1757-1765). The upper half is a modern view, facing westward. The older buildings date from the early 1800s and have replaced the original wooden structures. The apothecary where Scheele worked (Enhörningen: "Unicorn"; marked with an arrow) is now a beauty salon (13 Sodra Hamngatan ("South Harbor Street"; N 57° 42.35; E 11° 57.84). The lower half is from the time of Scheele, facing eastward. The Unicorn pharmacy is marked with an arrow. Across from the apothecary was situated the auction and warehouses for the East India Company, now the location of the historical Stadsmuseet. In both halves the Christine Kyrka (Christine Church) can be identified (upper: right; lower: left).

Figure 5. This is the location in Malmö (Gustaf Adolf Torget 10/Tullgatan 1) of the pharmacy (Fläkta Örn: "Spread Eagle") where Scheele worked during 1765–1768. Here he first observed "sparks above saltpeter" which eventually led to his discovery of oxygen. The original building structures have been replaced by late nineteenth century buildings. The site of the pharmacy (at the corner of the building) is now an elegant boutique (N 55° 36.13; E 13° 00.02).

At 23 years of age, Scheele moved on to Malmö (Figure 5) where he had the advantages of a good laboratory, and it was here he conducted his first serious experiments. He established a relationship with Anders Jahan Retzius (1742–1821),[7] a demonstrator and later professor at the University of Lund (15 kilometers to the northeast). Letters from Scheele to Retzius exist[8] that allow us to gain a glimpse of his growing experience and concepts of chemistry at this time. In these letters Scheele gives a detailed description of his investigation of saltpeter and nitrous acid. In his classic treatise *On Air and Fire*,[9] written a decade later in Uppsala, Scheele describes his observation "how air-born bits of carbon were ignited from air generated from the boiling saltpeter." What he was observing was the spontaneous ignition of charcoal with generated oxygen, and he first observed this in Malmö. We can be fairly certain that this was the key observation that excited his imagination and later led to the formal discovery of this gaseous element.[5]

While living in Malmö, Scheele visited his parents for the first—and last—time. For the remainder of his life he remained in Sweden, never again travelled to the main continent.[5]

Three years later, Scheele moved to Stockholm where he worked at a pharmacy in the Old Town (Figure 6), which is popular today with tourists visiting the royal castle and its environs. This pharmacy was only a shop and Scheele had to conduct his experiments elsewhere in Stockholm (Figure 7).[2] It was during this time (1768–1770) that Scheele conducted most of the experiments described in *On Air and Fire*.[9] It is quite possible that Scheele had some working knowledge of oxygen by this time: an anecdotal story relates that students at the Seraphimer hospital once posted a sign on

Figure 6. In "Old Town" (Gamla Stan) of Stockholm, this structure housed the pharmacy (Förgyhllda Korpen: "gilded raven") where Scheele worked 1768-1770. Today this building (Stortorget 26; N 59° 19.51; E 18° 04.23) boasts a quaint coffee shop, and is one of the many historic tourist attractions. The pharmacy was moved in 1924 to its modern site (100 meters to the northwest; 16 Vasterlanggatan, N 59° 19.54; E 18° 04.13; not shown) and possesses an attractive and detailed exhibit on Scheele. The Raven pharmacy was founded in 1674 by Jürgen Brandt, father of Georg Brandt, the discoverer of cobalt.[24]

Figure 7. It is possible that Scheele first developed some working knowledge of oxygen here in the old Seraphimerlassarettet (Seraphimer Hospital),[10] *(2F Serafimergrand; N 59° 19.70; E 18° 03.12) found on Kungsholmen island of Stockholm, across the street from the Stadtshuset (City Hall). The door shown in the photograph is the original. This building housed the Chemicum Laboratorium of the Royal Mint 300 years ago. The modern Seraphimer hospital is to the far right.*

Figure 8. Upper half: the modern Åhléns department store is located at the site of the pharmacy (Uplands Vapen: "Uplands Arms") where Scheele worked 1770-1775 (Stora Torget & Kungangsgatan; N 59° 51.50; E 17° 38.37). Lower half: photograph of the pharmacy 100 years ago. Only 200 meters northwest is the Celsius house, where the astronomer Anders Celsius proposed his new temperature scale two years before Scheele's birth; 300 meters further northwest are the famous Linnaeus gardens. Scheele associated a great deal with Torbern Bergman of the University, 300 meters to the south.

Figure 9. This Minnemärk (memorial) of the "Scheele stone" was on exhibit at the modern Uplands Vapen pharmacy (Svavagallerian, 50 Dragarbrunnsgatan; N59° 51.50 E17° 38.58) of Uppsala during the period 1990-2000. The modern pharmacy still possesses a small display on Scheele, but this "Scheele stone" is now in the Upplandsmuseet storage at Morgongåva, 40 kilometers to the west. This stone plaque, engraved by the Swedish Royal Academy, was once posted on the original site (see Figure 8) and translates: "In this house lived Carl Wilhelm Scheele 1770-1775. Here he discovered oxygen and other natural elements."

the cloakroom: "Here Scheele discovered oxygen. When he left he took it with him."[20]

Scheele had high expectations from his time at Stockholm, but he was frustrated by the lack of facilities and opportunities. He moved to Uppsala to work in a pharmacy near the University (Figure 8), where he met Johann Gottlieb Gahn,[11] who introduced him to Torbern Bergman (1735–1784), the well-known professor of chemistry and pharmacology at the University of Uppsala. The association between Bergman and Scheele was mutual good fortune—Scheele was introduced to the international scientific world, while Bergman enjoyed his "greatest discovery"[2] [Scheele] who brought true genius to his University. Bergman urged Scheele to work on pyrolusite (MnO_2) which led to the discovery of chlorine (by reacting hydrochloric acid with pyrolusite), a new synthesis of oxygen (by reacting sulfuric acid with pyrolusite), and the isolation and characterization of baryta (barium earth) which was an impurity in pyrolusite.[23] Working with gases, Scheele identified nitrogen and hydrogen fluoride, and he wrote *On Air and Fire*,[2] which includes his discovery of oxygen.

By now Scheele had risen to great fame throughout Europe, and he was given offers to work in prestigious locations elsewhere in Europe. However, he preferred obscurity and located a pharmacy in Köping that he could have for his own (Figure 10). Here he made his studies on organic compounds, and he discovered molybdenum and tungsten earths and prepared pure oxides of each. He discovered "Scheele's green" (copper arsenite) which was soon adopted as a dye in wallpapers and fabrics throughout Europe. In the 1700s, all pharmacists smelled and tasted their preparations, and he found that the gas prepared by distilling potassium ferrocyanide with sulfuric acid had "a peculiar, not unpleasant smell" and "a taste which almost borders slightly on sweet and is somewhat heating in the mouth"[2]—he had discovered hydrogen cyanide. It is no wonder that Scheele died of health complications at such an early age: he had been exposed for years to a noxious atmosphere of not only hydrogen cyanide, but also chlorine, hydrogen sulfide, carbon monoxide, and hydrogen fluoride.[3]

With his incredible memory Scheele committed virtually everything to memory—but he wrote little. He performed over 15,000 experiments in his lifetime, but only a few scraps of laboratory notes and correspondence exist; he generally wrote only when prompted by his colleagues. He drove himself incessantly, laboring every evening in his laboratory after performing his daily apothecary chores. Sir Humphry Davy (1778–1829) said of him, "Nothing could damp the ardour of his mind or chill the fire of his genius: with very small means he accomplished very great things."[2]

The Discovery of Oxygen. In the fanciful play *Oxygen* by Roald Hoffmann and Carl Djerassi,[12] it is suggested that oxygen was the most important of all elemental discoveries, because with

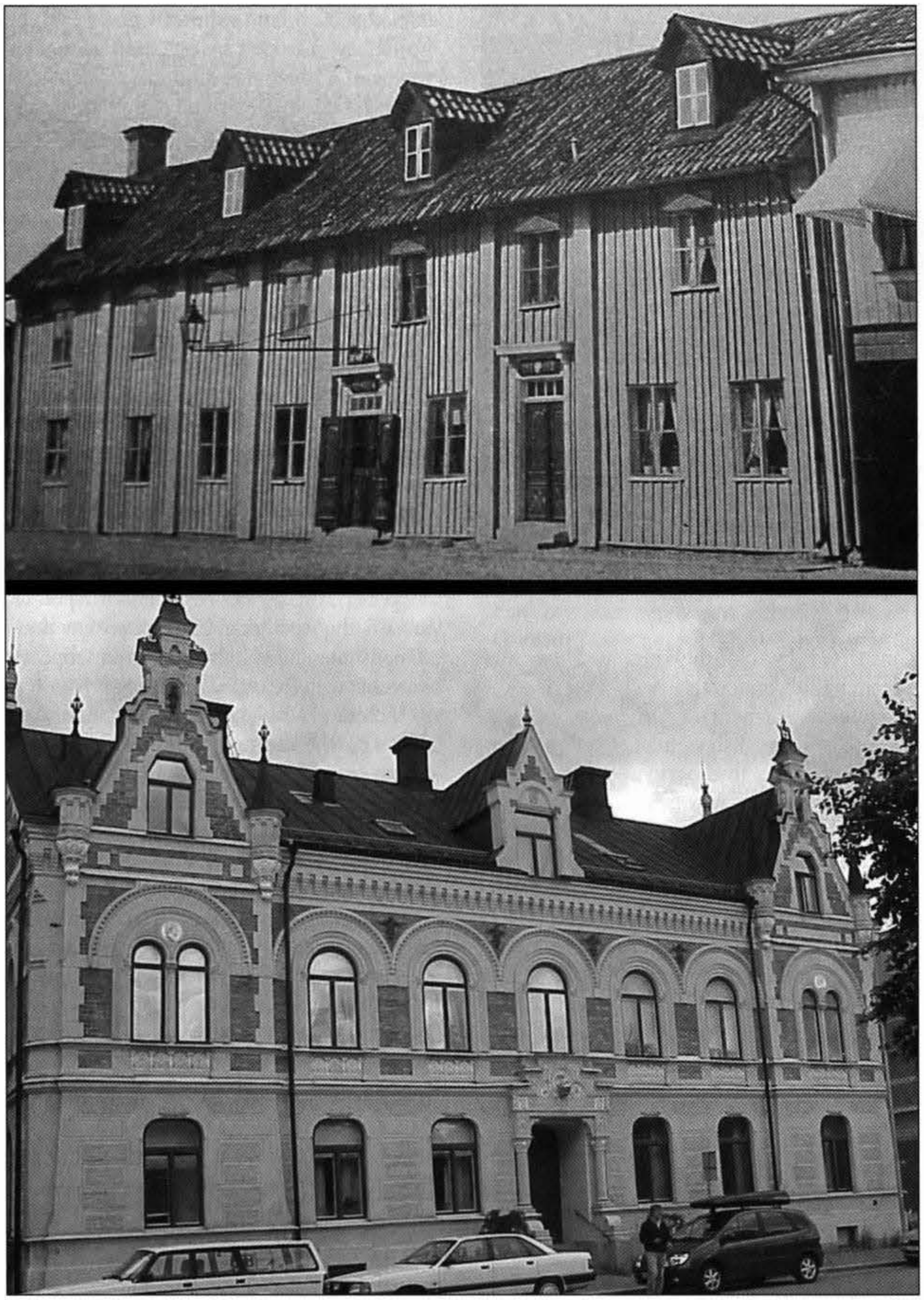

Figure 10. Upper half: this was the old pharmacy (Lejonet: "The Lion") where Scheele spent the last 11 years of his life. It burned down in 1899, caused by a careless boy playing with matches. Lower half: the site is now occupied by a modern building (Apotekshuset, 2 Stora Torget; N 59° 30.85; E 15° 59.56), directly across from the Scheeleparken and the churchyard where Scheele is buried.

its study by Lavoisier[2] came a fundamental revolution of chemistry itself, and leading to our modern view of the science. Most of the play is devoted to arguing who the "true" discoverer of oxygen was. This question is never resolved, because the discovery of an element involves several criteria, including isolation and description; publication of the research; and understanding that the new substance is indeed an element.[13] Although Scheele was the first to isolate and describe the element, Priestley published first. Yet neither of these two scientists understood the true nature of what they had found. Priestley remained unshaken in his conviction that oxygen was dephlogisticated air. However, Scheele was more advanced in his chemistry and was beginning to doubt the validity of the phlogiston theory; he believed heat was a component of oxygen, which he named Feuerluft (fire air) in *On Air and Fire.*[4] It took Lavoisier, with his research culminating in his *Traité*[1] in 1789, to understand that oxygen (which he named) was an element, finally overthrowing the theory of phlogiston. But the fact remains: Scheele was the first to prepare and characterize oxygen.[3]

Figure 11. The Köpings Museum (Östra Långgatan 37; N 59° 30.50; E 16° 00.01), 700 meters to the southwest of the original Scheele apothecary, has a beautiful display on Scheele and his apothecary, occupying several spacious rooms.

Although much of the play is imaginary, one detail is not: the "Lost Letter"[14] of 1774 written by Scheele and sent to Lavoisier, wherein Scheele suggests that Lavoisier use the Tschirnhausen lenses[15] to heat the precipitate of lapis infernalis (lunar caustic, $AgNO_3$) with alkali of tartar (K_2CO_3)—that is, silver carbonate, Ag_2CO_3. It is clear[16] that Scheele had previously performed the experiment (albeit with inferior lenses); he realized that heating silver carbonate will produce both fixed air (carbon dioxide) and "vitriolic air" (an earlier name given to oxygen by Scheele):

$$\text{precipitate } (Ag_2CO_3) + \text{heat} \rightarrow \text{silver} + \text{fixed air } (CO_2) + \text{vitriolic air } (O_2) \quad (1)$$

Much of the play *Oxygen* is devoted to whether or not Lavoisier took this information to his advantage (or if he even read the letter), and to what extent Scheele understood the phenomenon in question (Note 2).

Scheele eventually learned to produce oxygen by several methods, including heating mercury carbonate, mercury oxide, magnesium nitrate, nitric acid, a mixture of pyrolusite (MnO_2) and sulfuric acid, and a mixture of arsenic acid (which he had discovered) and magnesia nitra (manganese).[16] In his *On Air and Fire,*[9] Scheele purports the classic heating of a metal oxide to involve heat as a key ingredient which actually is a "compound" of Feuerluft (fire air) and phlogiston (φ):

$$\text{calx} + (\varphi + \text{fire air}) \rightarrow (\text{calx} + \varphi) + \text{fire air} \quad (2)$$

ie: [metal oxide] + heat → [metal] + [oxygen]

Even though Scheele recognized that air was in fact composed of two distinct substances—verdorbene Luft (N_2) and Feuerluft (O_2) (Swedish *skamd luft* and *elds luft,* respectively[17])— the fact that Scheele continued to use the concept of phlogiston is used by some as an argument that he was far from understanding the true nature of what he had

Figure 12. Oliver Sacks, author of Uncle Tungsten, lays a wreath on the grave of Carl Wilhelm Scheele, October 13, 2003 (N 59° 30.79; E 15° 59.43).

discovered.[18] However, Boklund observes[16] that Scheele had long been troubled by the concept of phlogiston and was using the term only as a convention (Note 3). Scheele, as all chemists, was well aware that "phlogiston could be added" (e.g., as charcoal) to a calx to produce a metal—and yet "phlogiston" was not needed at all to explain the "Lost Letter" reaction (1). Furthermore, Scheele showed that he could regenerate silver repeatedly without any addition of phlogiston:

silver + nitric acid $\rightarrow$ solution
i.e., $Ag + HNO_3 \rightarrow AgNO_3\,(aq)$ (3)

solution + potassium carbonate (alkali of tartar) $\rightarrow$ precipitate (Ag_2CO_3) (4)

precipitate (Ag_2CO_3) + heat $\rightarrow$
silver + fixed air (CO_2) + vitriolic air (O_2) (1)

repeat the reactions (3), (4), (1) . . . .

This mystery had bothered Scheele apparently since his days in Malmö.[16] Other examples that disturbed Scheele included the heating of saltpeter (potassium nitrate), which could produce oxygen by just heating.[16]

Unfortunately, Scheele was not aware of the key experiment of Lavoisier: that hydrogen and oxygen react to produce water—Scheele apparently interpreted any moisture as being a residue of his baths and missed this critical observation.[2] In every reaction where Scheele produced oxygen, he saw that *heat* effected change. To him heat was always necessary for producing oxygen, and he concluded there was something substantial about heat itself. Thus, the concept of Feuerluft being a compound followed naturally.

Scheele was not a theorist but instead a practical chemist. Hence, he was not a phlogistonist at heart,[16] his interpretations were not constricted by old thinking, and he was becoming uncomfortable with the classical Aristotelian elements.[16] Originally Scheele accepted Cavendish's interpretation that "inflammable gas" (hydrogen) was phlogiston—Scheele refers to his new method of "preparing phlogiston" in 1769 by reacting iron with water over a 2-month period at room temperature.[16] Later, however, he refers to the gas not as phlogiston, but simply as another substance.[16]

Noticing that calx weighs more than metal, Scheele proposed that "fire air" might in fact reside in calx.[29] It is easy for us to see that with this observation, if Scheele had merely subtracted φ from both sides of equation (2), he would have Lavoisier's view of oxidation. One wonders, if there were no Lavoisier, and if Scheele had lived beyond 44 years, would Scheele have come to the same interpretation independently? Unfortunately, we will never know.

The Legacy of Scheele. *Skansenparken.* Much of the equipment and supplies of Scheele's Köping pharmacy has been transported to Skansen Park in Stockholm and has been arranged in a cottage (Apoteket Kronan, N 59° 19.58; E 18° 06.05) modeled after the pharmacies of Scheele's time. Skansen Park, covering many acres, has been developed to preserve the history of Sweden by moving onto its premises about 150 Swedish historical houses, complete with interiors, dating from the 1700s and 1800s. Visitors to each house are met by persons in period costume. In Apoteket Kronan, the "apothecary" in 18th century dress demonstrates how 18th century prescriptions were made up for various ailments.

"Scheeles Minne" ("in the memory of Scheele"). The Köping Museum has a generous display of exhibits dedicated to the memory of Scheele. Several rooms are devoted to displays of laboratory equipment, collections of minerals and chemicals, pharmaceuticals, maps, and descriptions of the times and life of Scheele. The dedicated staff are keen in their upkeep of the museum and the spirit of Scheele. Last year Oliver Sacks, the author of *Uncle Tungsten*, visited the museum to view the displays and participate in some of the ceremonies commemorat-

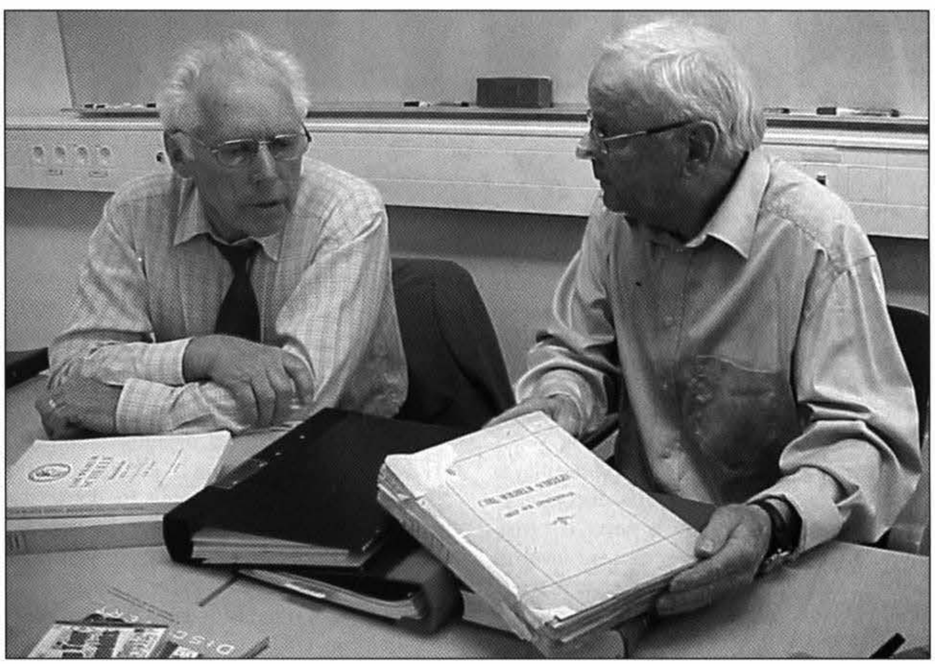

Figure 13. The best scholars of Scheele today: Per Enghag (left), author of reference 17, and Rolf Norin (right), Professor at the University of Linköping. Dr. Norin is holding an original manuscript (reference 8) by A. E. Nordenskiöld, biographer of Scheele.

ing Scheele, including a stage production of the museum staff and a graveside dedication. Feeling a kinship with Scheele who truly loved science in a youthful curiosity, Sacks laid a bouquet of flowers on the grave of Scheele with such reverence and pathos that he "brought tears to the eyes of the spectators." (Figure 12). Future visitors to the museum can share in this spirit and sign the guest book as did Oliver Sacks, whose entry echoes his *Uncle Tungsten*: "Beautiful museum! Lovely to see these memorials of my boyhood hero Scheele."

Acknowledgments.

The authors are indebted to Dr. Rolf Norin, Professor of Chemistry at the University of Linköping and a scholar of Carl Wilhelm Scheele, for much valuable guidance and information. A delightful day was spent at Linköping with Dr. Norin and Dr. Per Enghag (author of reference 17) discussing the history and chemistry of Scheele (Figure 13). The authors also acknowledge with gratitude the help of Ingela Räder and Lars Asplund at the Köping Museum, who furnished much of the biographical information and who were particularly helpful in locating all sites of Scheele's pharmacies. Ms. Räder and Mr. Asplund serve as the actors of Sara Margaretha Pohl (the owner of the Köping pharmacy, who married Scheele three days before his death) and Carl W. Scheele during commemorative presentations at the Museum. Finally, the assistance of Oliver Sacks (who furnished Figure 12) and Roald Hoffmann (who clarified key points about the play *Oxygen* and who made other suggestions) is acknowledged. ○

Notes.

Note 1. This statement embodies only natural elements and excludes the Guinness World Record of Albert Ghiorso[19] who discovered or co-discovered 12 artificial, transuranium elements. Scheele can claim the discovery and recognition of seven elements: chlorine and oxygen (in elemental form); manganese, barium, molybdenum, and tungsten (as earths); and fluorine (as hydrogen fluoride). Humphry Davy did not discover, but prepared in the elemental form, the eight elements Li, B, Na, Mg, K, Ca, Sr, and Ba. The authors concede freely that recognizing the "true discover" can be a complex business[13] and that for several elements more than one claim for discovery can be made—for example, Scheele's chlorine undoubtedly was a mixture including air, and pure chlorine and the true nature thereof was not recognized until Davy[2, 20] in 1810; Daniel Rutherford also discovered nitrogen ("phlogisticated air"), simultaneously with Scheele; for oxygen three claims to the discovery may be made, each based on a different criterion,[12] etc., etc. However, in these "Rediscovery" series the authors, in order to maintain a free-flowing travelog, have adopted a full inclusive policy; they address elsewhere the contentious issue of priority of discovery.[21]

Note 2. The note written by Madame Lavoisier to her husband in *Oxygen*[22] (explaining she intercepted Scheele's letter but hid it from him) is fictional.[22] The 1774 letter from Scheele to Lavoisier was found by Édouard Grimaux in the archive of Lavoisier a century after it was written;[23] a draft of the original letter is archived in Stockholm.[14, 16] In this letter Scheele concludes, "I hope you will see how much air is produced during this reduction and whether a lighted candle can maintain its flame and animals live in it,"[16] which essentially announces the discovery of oxygen. The significance of this letter would not have been missed by Lavoisier. Boklund argues forcefully that Lavoisier surely saw Scheele's letter.[14, 16] Grimaux, after he published Scheele's letter, paradoxically disavowed the importance of it and maintained his undiluted praise of Lavoisier: "Diminuer la part de gloire de Lavoisier, c'est dimimuer la patrimoine de l'humanité"[24] ["To diminish Lavoisier's part of the glory is to diminish the legacy of mankind"].

Note 3. Little remains of Scheele's personal writings. A. E. Nordenskiöld, the arctic explorer, published a work on letters and observations of Scheele[8] a full century after the chemist's time, but he did not tackle the remaining laboratory notes of Scheele, collected in the so-called "Brown Book" (*Bruna boken*). These notes were an almost undecipherable mixture of alchemical notes, Latin, and German. Not until the mid-twentieth century were these *Bruna boken* notes of Scheele translated and interpreted by Uno Boklund (1897–1975),[16] who has shed much light on the evolution of Scheele's chemical sophistication.

Note 4. Another statue of Scheele has been sculpted by J. L. H. Börjeson, situated (N 59° 20.41; E18° 04.51) in Humlegården (large city park) of Stockholm; this statue portrays a different physiognomy. There is no known detailed portrait of Scheele (despite earlier statements to the contrary in the literature[18])—all have been created from imagination or from comparison with relatives. However, three years after his death the Swedish Academy struck a medal with his image (see Inset, Figure 1); since many people at the academy had known him we may suppose that the likeness may be close.

References.

1. A.-L. Lavoisier, *Traité Élémentaire de Chimie*, **1789**, Paris.

2. J. R. Partington, *A History of Chemistry*, Vol. 3, **1962**, Macmillan (London), 205–234.

3. O. Zeckert, *Carl Wilhelm Scheele. Apotheker, Chemiker, Entdecker*, **1963**, Wissenschaftliche Verlagsgesellschaft m. b. H., Stuttgart.

4. S. E. Sheppard, *J. Chem. Ed.*, **1927**, 4(3), 298–312.

5. O. Zekert, *Carl Wilhelm Scheele. Sein Leben und seine Werke*, **1931–1933**, Buckdruckerei Arthur Nemayer, Mittenwald (Bayern).

6. Partington, *op. cit.*, Vol. 2, 361–377.

7. Ibid, Vol. 3, 200.

8. A. E. Nordenskiöld, *Carl Wilhelm Scheele. Efterlämnade bref och anteckningar [Posthumous letters and notes]*, **1892**, Stockholm.

9. C. W. Scheele, *Chemische Abhandlung von der Luft und dem Feuer* ("Chemical Treatise of Air and Fire"), **1777**, Upsala und Leipzig, Verlegt von Magn. Swederus, Buchhändler.

10. J. Erik Jorpes, *Bidrag Till Kungl. Svenska Vetenskapsakademiens historia. VII. Jac. Berzelius. His Life and Work*, **1966**, English translation by Barbara Steele, Almquit and Wiksell (Stockholm), 18.

11. J. L. Marshall and V. L. Marshall, *THE HEXAGON of Alpha Chi Sigma*, **2004**, *95* (3), 46–50.

12. C. Djerassi and R. Hoffmann, *Oxygen*, **2001**, Wiley-VCH (New York).

13. P. Walden, *J. Chem. Ed.*, **1952**, *29*, 304–307.

14. U. Boklund, "A Lost Letter from Scheele to Lavoisier," *Lychnos*, **1957–1958**, *17*, 1–24.

15. Marshall, *op. cit.*, 95(4).

16. U. Boklund, *Carl Wilhelm Scheele. His Work and Life*, Vol. I/II (*The Brown Book*), **1968**, Roos Boktryckeri (Stockholm). Translation of *Bruna boken*, **1961**.

17. P. Enghag, *Jordens Grundämnen och deras upptäckt [The earth's elements and their discoverers]*, **1998**, Industrilitteratur, Stockholm. This book has been expanded and translated into English: *Encyclopedia of the Elements*, **2004**, Wiley-VCH, Weinheim.

18. M. E. Weeks, *Discovery of the Elements*, 7th Ed., **1968**, Journal of Chemical Education, 225.

19. C. Folkard, ed., *2003 Guinness World Records*, **2003**, Gullane Entertainment (London), 273.

20. Partington, *op. cit.*, Vol. 4, 32-75.

21. J. L. Marshall and V. L. Marshall, *Bull. Hist. Chem.*, **2003**, 28(2), 76–83.

22. R. Hoffmann, private communication.

23. É. Grimaux, *Revue Générale des Sciences pures et appliquées*, L. Oliviers, ed., **1890**, No. 1 (Jan. 15), 1.

24. É. Grimaux, *Lavoisier 1743–1794*, **1888**, Paris.

25. J. L. Marshall and V. L. Marshall, *THE HEXAGON of Alpha Chi Sigma*, **2003**, *94 (1)*, 3-8.