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Note/*Notes*

CARL WILHELM SCHEELE - HIS LIFE AND SCIENTIFIC ACHIEVEMENTS

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SUMMARY

Carl Wilhelm Scheele must be regarded as one of Sweden greatest chemists. He was born in 1742 in Stralsund, where he grew up in a family well-known in northern Germany since the 15th century. He chose the pharmaceutical profession early and was only 15 years old when he left his home town for educational studies at the Unicorn pharmacy in Gothenburg in Sweden. The apothecary there, Martin Andreas Bauch, was a native of Mecklenburg with good relations to the Scheele family. Scheele came to stay in Sweden for the rest of his life and since 1775 he worked as an apothecary in the small town of Köping.

In Sweden Scheele established a close friendship with Torbern Bergman, in his time one of the most leading chemists, and the friendship was a prerequisite for Scheele's breakthrough as a scientific writer. His first paper was published in 1771 and was followed by another thirty publications. Scheele's major work was " Chemische Abhandlung von der Luft und Feuer", where he describes the discovery of oxygen. Scheele remained a pharmacist and was working most of his time as an apothecary in Köping. However, he became early accepted as a scientist with an internationally good reputation. He was elected as a member of several academic societies. During his life he discovered seven elements – more than any other chemist has detected - and most of his about 20.000 laboratory notes have still not been examined. He died only 43 years old. He is buried in Köping. On his gravestone we can admire a statue of a torch-carrying genius.

Key words: Carl Wilhelm Scheele

Introduction

Through the Westphalian Peace Treaty in 1648, following the 30-Year War, Sweden gained possession of some parts of northern Germany, including Vor-Pommern with the town of Stralsund. These regions came to belong to Sweden until the Vienna Congress in 1814. Very soon close cultural and scientific relations were established between Sweden and her German possessions. Many Germans moved to Sweden to study or to work, often remaining permanently.

Carl Wilhelm Scheele was born on the 9th of December in1742 in Stralsund, where his father was a merchant and of a family well-known in northern Germany since the 15th century. Carl Wilhelm was the seventh of eleven children. Not much is known about his childhood. He went to school in Stralsund, but throughout his schooling he does not seem to have shown any indications of his future development as an outstanding scientist.

Two of the Scheele brothers chose the pharmaceutical profession, not only Carl Wilhelm but also Johann Martien, who was eight years older than Carl Wilhelm. The reason, or one of the reasons, for their choice of profession could have been the influence of Cornelius, the apothecary, and Schütte, the physician, in Stralsund, both of whom were friends of the Scheele family. Certainly, Carl Wilhelm was also influenced by his older brother. Johann Martien went to Sweden in 1748 where he started off as an apprentice at the Unicorn pharmacy in Gothenburg. Unfortunately, he died of typhus as early as in 1754[1].

Scheele leaves Stralsund for Gothenburg in Sweden

Even Carl Wilhelm chose the Unicorn for his education and began his apprenticeship there in 1757, not yet 15 years old. The apothecary at the Unicorn pharmacy was Martin Andreas Bauch. He was a native of Mecklenburg and was related to the Scheele family. This was certainly a reason for the young Scheele brothers to choose his


Carl Wilhelm Scheele's
d. Königl. Schwed. Acad. d. Wiſſenſchaft. Mitgliedes,
Chemiſche Abhandlung
von der
Luft und dem Feuer.
Nebſt einem Vorberichte
von
Torbern Bergman,
Chem. und Pharm. Prof. und Ritter, verſchied.
Societ. Mitglied.
Upſala und Leipzig,
Verlegt von Magn. Swederus, Buchhändler;
zu finden bey S. L. Cruſius.
1777.

Fig.1 - Scheele's work "Chemische Abhandlung von der Luft und Feuer", where he describes the discovery of oxygen

local pharmacy for their education. In fact, Bauch's three predecessors at the Unicorn pharmacy all had come from Germany, a situation applying to most of the apothecaries in Sweden during the 17th and the 18th century. Having established himself in Gothenburg, Scheele came to stay in Sweden for the rest of his life. He lived in five cities: Gothenburg, Malmö, Stockholm, Uppsala and Köping.
The apothecary at the Unicorn pharmacy enjoyed a very good reputation as an able pharmacist, and his apprentices were given a fine education during the six years under his tutorage. The person who

was more closely involved in Scheele's education was, however, a pharmacist called Grünberg, who later became an apothecary in Stralsund. Scheele's great interest in chemistry was soon aroused, which was early realized by Bauch, who gave Scheele considerable latitude to pursue chemical experiments. Helped by Grünberg and aided by the scientific literature at the pharmacy, he began to examine the approximately 80 different chemicals on the shelves - acids, bases, salts and so on - and it is said that, for each of them, he found a new property or made a new observation. Already as an apprentice Scheele thus proved himself to be an excellent experimenter, possessing acute powers of observation. He seems, however, to have worked without any real plan. No notes are kept from his experiments[2].

Scheele meets the scientist Anders Retzius

Scheele extended his stay at the Unicorn pharmacy after his apprenticeship. He now became a laboratory worker, which enabled him to continue his experimentation. However, when Bauch sold his pharmacy in 1765, Scheele preferred to leave and chose to move on to Malmö and the Spread-Eagle pharmacy. The reason for his choice may lie in the fact that the apothecary of Spread-Eagle, Peter Magnus Kjellström, like Scheele, had been one of Bauch's apprentices. He also had a keen interest in chemistry.

Even in Malmö Scheele worked in the laboratory, and he was permitted the same opportunities to run experiments as had been given to him in Gothenburg. Scheele soon became acquainted with Anders Jahan Retzius, who was of the same age as Scheele and who had passed an apothecary examination some years before they met. Retzius now also had a doctor's degree in chemistry at the University of Lund. A lifelong friendship was established between these two, and Retzius would be of great importance for Scheele's scientific progress. We must remember that Scheele lacked academic training.

He had achieved his chemical knowledge exclusively from self-instruction and practical work in a pharmacy. It was Retzius who urged Scheele to start keeping accurate notes from his experiments. From Malmö, Scheele sent his first two papers to the Academy of Sciences in Stockholm. The Secretary remitted the papers to the professor of chemistry at the University of Uppsala, Torbern Bergman, who, however, rejected both of them. They were never

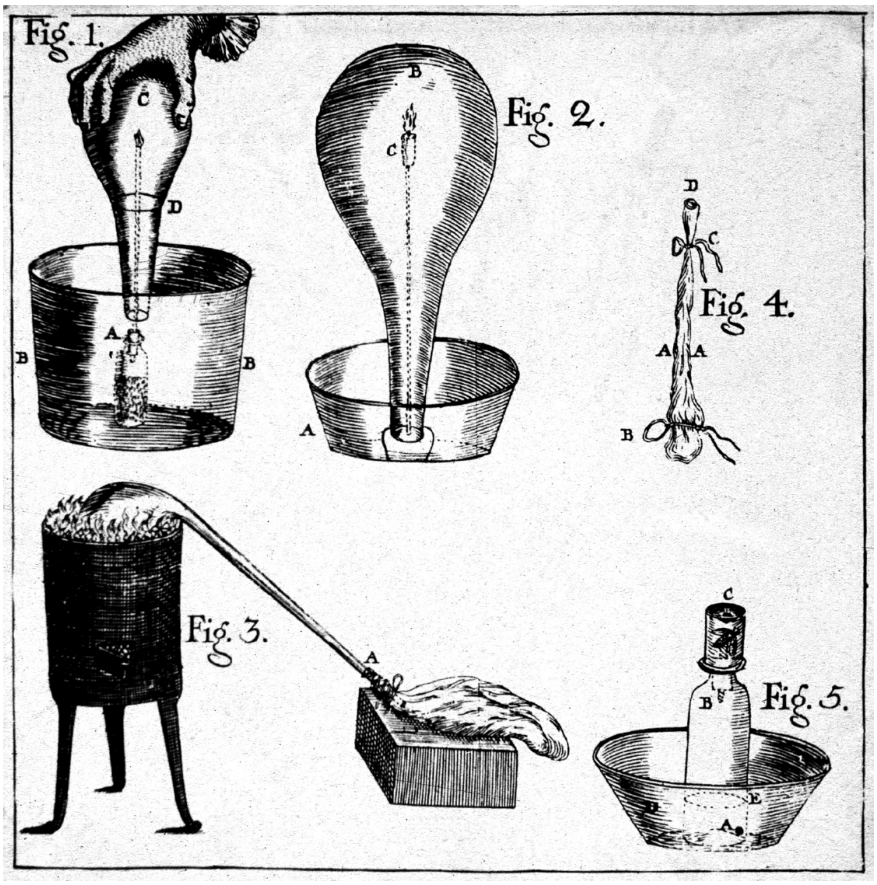

Fig. 2 - Instruments used by Scheele in his laboratory work

to be published. Scheele's career as a scientist could have started better, and he held a grudge against Bergman for a long time. This, however, would change when they later met in Uppsala.

In Malmö, Scheele started an investigation of tartar (potassium bitartrate), and he was the first to isolate tartaric acid. He described this work to Retzius, who repeated the experiments, after which the two friends agreed that the paper should be sent to the Academy in the name of Retzius. The paper was published in the Transactions of the Academy in 1770 -*"Experiments with tartar and its acid"* - and Retzius reported that Scheele, a clever *pharmaciae studiosus,* had isolated an acid from tartar, with properties different from all other acids. Scheele's name was in print for the first time[3].

Scheele also made the important discovery of the nitrous acid, which, however, was never published. During these experiments Scheele stumbled onto some problems which forced him to include air and fire

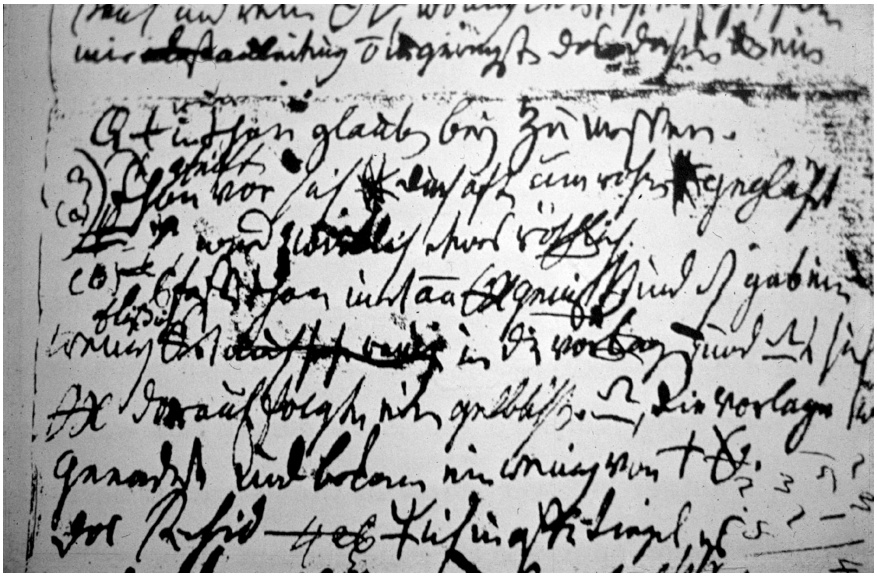

Fig. 3 - Laboratory notes showing Scheele's hardly legible handwriting

in his investigations. By doing so, he entered into a field of research which would later become the most important of all, leading to the discovery of oxygen. While in Malmö, Scheele demonstrably also prepared oxygen by heating saltpetre, which decomposed into nitrite and a gas, but at that time he did not know the nature of the gas. From Scheele's time in Malmö, mention may be made of his investigations on Prussian blue which, fifteen years later, was to result in the discovery of hydrocyanic acid.

Scheele stayed in Malmö for no more than three years. Before moving to Stockholm and the Golden Raven pharmacy in 1768, he made his only return visit to his home in Stralsund. The reason for moving to Stockholm was undoubtedly due to that Scheele wished to be close to the scientific centre of Sweden in order to establish contacts with the scientists there. Even if he was successful in that respect, the job at the pharmacy did not reach up to his expectations. The apothecary at the Golden Raven, Johan Scharenberg, did not give him any opportunities to experiment like he had had formerly, and his principal occupation involved mainly making up prescriptions. Nevertheless, this did not prevent Scheele from making some interesting discoveries, for instance the observation that different parts of the solar spectrum have different capacities to blacken silver chloride. He also showed that bone ash - animal earth - contains calcium phosphate, and he succeeded in isolating phosphorus from this. Thus, from now on, it was no longer necessary to use urine for producing the phosphorus required for matches. Scheele also seems to have proceeded with his research on air and fire[4].

The cooperation with Torbern Bergman

After two years' stay in Stockholm, Scheele moved to Uppsala and the Arms of Upland pharmacy in 1770, where he once again became a laboratory worker. The apothecary at the pharmacy was Christian Ludvig Lokk, again a German, born in Hinter-Pommern and thus

a compatriot of Scheele's. Lokk was a highly committed pharmacist and Scheele was allotted one day a week for his own research. The famous university at Uppsala had 24 professors, among them Carl von Linné, 63 years old and still going strong. Another one was Torbern Bergman, astronomer, entomologist, meteorologist, physicist, mathematician and also a brillant chemist. These two academics and Scheele were to become the greatest scientists in Sweden during the 18th century.

After a short time Scheele met Bergman, and despite the earlier grudge on Scheele's part, a close friendship soon arose between the two, which lasted until Bergman's death in 1784. An extraordinary state of cooperation began between Scheele and Bergman, which is fairly unique in the history of chemistry. On the one hand, we had the highly educated professor of chemistry and, on the other, the self-taught laboratory worker in the pharmacy. After Scheele's death, his friend Retzius said that it sometimes was difficult to know which of the two was the teacher and which was the student. It is also difficult to decide what impact each of them had had on more or less common discoveries. Someone has said that the greatest of Bergman's achievements was his discovery of Scheele. It is to the honour and credit of Bergman that he never showed any signs of envy or jealousy when Scheele's reputation soared to such a height that it seemed to put Bergman's own in the shade.

The excellent relationship between Scheele and Bergman was a prerequisite for Scheele's breakthrough as a scientific writer. His first paper was published in the Transactions of the Academy of Sciences in 1771 and it was to be followed by another 30 papers. A few minor contributions were published in some foreign journals, for instance the Crells Chemische Annalen. Scheele's major research on air and fire was the only work to be published as a separate monograph.

The first paper was *"On fluor spar and its acid",* in which Scheele describes a new acid which corrodes the internal surface of the

retort, and which also contains a new element. This element, fluorine, was however not isolated until 1886 by the French chemist Henry Moisson.[5] Scheele's most important paper published in the Transactions of the Academy is generally considered to be *"On Brownstone or Magnesia and its properties"* from 1774. This investigation was carried out on Bergman's initiative and resulted in the discovery of three new elements. The first one was chlorine, prepared by heating brownstone and hydrochloric acid[6]. However, Scheele did not look upon chlorine as an element, which was not verified until 1810 by the English chemist Humphry Davy. Chlorine was exploited as a bleach by the textile industry as early as in the 1780's. The second element was manganese. Scheele was, however, not able to isolate the metal since he had no furnace with a sufficiently high temperature. The element was isolated later on by his friend Johan Gottlieb Gahn according to Scheele's instructions. The third element was barium, isolated as barium oxide. The brownstone was namely mixed with barium salts. The metal itself was isolated around 1808 by the Swedish chemist Berzelius as well as by Davy.

Fig. 4 - The portrait of Scheele on the medal coined by the Academy of Sciences in 1789

Scheele becomes the owner of the pharmacy in Köping

In 1775 Scheele was elected a member of the Academy of Sciences, an unprecedented mark of honour as he still was a non-graduate. Scheele now had reached a respected position in the scientific world, and he seemed to get along well in Uppsala. At the pharmacy, however, his position was subordinate. He was 32 years old, and his title was still *Pharmaciae Studiosus*. Perhaps it is not surprising if he now and then wished to find a more independent position, and we must remember that Scheele was a pharmacist by profession. His chance arose in the spring of 1775, when the pharmacy in Köping, a small town 120 km southwest of Uppsala, became vacant. The apothecary had died, and his widow, in order to retain the privilege, had to employ a qualified head for the pharmacy. If Scheele moved to Köping it would give him the possibility to become the owner of the pharmacy later on. He probably also believed that, in his own pharmacy, he could devote more time to his research. After discussion with his friends, Scheele made up his mind and in the summer of 1775 he moved to Köping. He came to an agreement with the widow that he would be the Head of the pharmacy for one year as a start, and subsequently he would be allowed to continue at this position for another year, if he so wished. When Scheele had moved from Uppsala, Bergman wrote a letter to Gahn

> *Now Scheele has left. It was a distress for both of us to part; he manages the Köping pharmacy and might perchance decide on the widow.*

By rights, Scheele now had to submit to his "provisor's" examination before the Collegium medicum, but as he was already very familiar to the Collegium, he was allowed a postponement of the examination. From some letters, we can deduce that Scheele was very happy during the first months in Köping. He divided his time between the pharmacy and a primitive laboratory in an outhouse. He

now finished the manuscript of his book on air and fire and sent it to a printer in Uppsala in December 1775. He also seems to have had plans for marrying the widow, who was only 24 years old and had a little son, not yet one year old. Troubles in which her father was involved arose and Scheele had other things to think about. Instead of marrying the widow he appointed her as his housekeeper, but his businesses with the widow were not yet finished[7].

The discovery of oxygen

Scheele's major work, *"Chemische Abhandlung von der Luft und Feuer",* was not published until August 1777 and the long delay was due to various circumstances, one of them being that Torbern Bergman did not finish his long preface until July 1777. As the title says, the book deals with air and fire, and Scheele now proves that the air is not an element - which many chemists still believed, two thousand years after Aristotle - but consists of two different gases. Scheele called the gases *fire air,* necessary for breathing, combustion, calcification, germination etc. and *bad air.* Scheele also describes several methods to prepare fire air, for instance by heating silver carbonate, mercury oxide, saltpetre and magnesium nitrate. By that Scheele had discovered oxygen, one of the most important discoveries in the history of chemistry[8]. However, already in August 1775 the English amateur chemist Joseph Priestley had published his discovery of oxygen from 1774, and Priestley therefore received the honour of the discovery. The French chemist Antoine Laurent Lavoisier was also involved in the question of priority. In the spring of 1775 he namely informed the French Academy of Sciences that he had discovered a new "entirely unknown kind of air".

The discovery of oxygen is of very great importance, but who was the real discoverer? The question was not definitively answered until 1892. In 1890 a letter from Scheele was found among Lavoisier's papers. The letter was dated in September 1774 and is sensational in

that Scheele, on account of some experiments described in the book, asks Lavoisier to heat silver carbonate with his big burning glass ...

> *which will show a new sort of gas being given off. The gas makes a candle burn brightly and can be breathed by animals.*

From this, it can be concluded that Scheele had already prepared oxygen but had kept it secret until the time of the letter. Lavoisier, however, seems to have ignored this message.

In October 1774, when visiting Paris, Priestley also informed Lavoisier about a new gas which he had prepared on the 1st of August in the same year by heating mercury oxide. He observed that a candle could burn with a particularly bright flame in the gas, but he assumed it to be laughing gas. Six months later he could show that it had a higher specific gravity and was easier to breath than ordinary air. Thus, Lavoisier had received very reliable information about Scheele's and Priestley's discoveries of oxygen, but he did not acknowledge it.

A definite proof of Scheele's priority to the discovery is to be found in the great Finno-Swedish polar explorer Adolf Erik Nordenskiöld's book *"Carl Wilhelm Scheele, posthumous letters and notes"* from 1892. Here Nordenskiöld reveals that Scheele had prepared oxygen already in 1771-1772 and also described its properties. The evidence is to be found in the laboratory notes from his first two years in Uppsala. Most people now agree that Scheele has the right of priority, but of course he and Priestley may share the honour of the discovery, which they made independently of each other[9].

With the discovery of oxygen, the chemical revolution - maybe of greater importance than the contemporary political revolution - evidently started. Despite his discovery of oxygen, Scheele's part in the chemical revolution is, however, of lesser importance. This was because he stuck to the phlogiston theory all his life. He was not able to understand correctly the role of oxygen in chemical reactions. The

person who drew the right conclusions was Lavoisier. He established the oxidation theory, and with this the phlogiston era came to an end. Chemistry could develop along new paths[10].

Member of the Academy of Sciences

In 1777, when Scheele's two years as the Head of the pharmacy in Köping had come to an end, he was able to purchase the pharmacy from the widow. He now had to pass his apothecary examination, and at the end of October he travelled to Stockholm. First, he took his seat in the Academy of Sciences with an initiation speech on *"How to prepare calomel by the wet method",* given in German and published in the Transactions of the Academy in 1778[11]. After the speech, he was heartily greeted by Torbern Bergman, who was the President that year. Some days later, he presented himself for his examinations in the presence of all members of the Collegium Medicum and the result was excellent. In his honour the Collegium freed him from paying the fee but expected him to assist with the revision of the pharmacopoea in recompense.

The following day Scheele visited the Academy once again and was then nominated for the Presidency for the coming year, together with three other members. However, in the drawing of lots among these four he lost. After his return to Köping he never again left this town, but he henceforth maintained good contacts by letter with leading chemists in Sweden and abroad.

Internationally, Scheele was now a scientist with a very good reputation, and in 1778 he was invited by King Fredrick the Great of Prussia to succeed the well-known chemist Andreas Marggraf at the Royal Academy of Berlin. Scheele, however, declined as he did not wish to leave Köping. In the same year he was appointed an honorary member of the "Gesellschaft Naturforschender Freunde" in Berlin.

The pharmacy which Scheele had purchased in 1777 was in a very bad condition, the laboratory being located in a dilapidated outhouse.

In 1781 he had the chance of purchasing a property located on the market square in Köping, where he had a new pharmacy built with a well-supplied laboratory. Unfortunately this house was demolished in 1889.

From Scheele's research and discoveries during his stay in Köping, the following may be mentioned. From his investigations of the two minerals molybdenic glance and tungsten, he discovered the new elements molybdenum and wolfram. In all, he had now discovered seven new elements, more than anybody else. He discovered uric, lactic, mucic, hydrocyanic, citric, oxalic, malic and gallic acids. Together with the tartaric acid mentioned earlier he had thus discovered no less than nine organic acids. Before Scheele and his work, only four organic acids were known: acetic, benzoic, formic and succinic acids.

Scheele not only discovered hydrocyanic acid, he also synthesized it, starting from carbon, potash and ammonium chloride. This is the first synthesis of an organic compound from inorganic materials and it took place 45 years before Wöhler's famous synthesis of urea, which has always been regarded as the first one. It is almost unbelievable to read the following words:

> *The hydrocyanic acid has a peculiar but not disagreeable smell, a taste somewhat approaching sweetness and warmth in the mouth, at the same time exciting coughing.*

Perhaps it is an understatement to point out that Scheele must have had good luck[12].

Scheele showed that graphite mainly consists of carbon and that the difference between malleable and unmalleable iron depends on different contents of carbon. He also showed that the so-called cold brittleness in iron and steel is due to contamination by phosphorus. He discovered a very good green paint, later called "Scheele's green"

or "Swedish green", consisting of copper arsenite. On account of its toxicity it is no longer used. When preparing ethyl acetate, Scheele discovered that phenomenon which Berzelius long afterwards called catalysis[13].

Scheele invented a new method to preserve vinegar, which is now called pasteurization. When preparing lead plaster (Emplastrum plumbi) by boiling lead oxide, olive oil and water, Scheele discovered glycerol and this is not yet the end of the list of Scheele's achievements[14].

This enumeration of the great chemist's discoveries, made during the short period of 15 years, shows the great scope and breadth of Scheele's research. It is astonishing how he succeeded in achieving that much along with his daily work in the pharmacy. He said on one occasion that, while his daily work was just a game, the explanations of new phenomena caused a lot of trouble.

Most of Scheele's approximately 20,000 laboratory notes have still not been scientifically examined. Many of them have not even been read because of Scheele's often completely illegible handwriting[15].

Scheele's last years

In addition to the marks of honour already mentioned, Scheele was called to become a member of the Academy of Sciences in Turin in 1784. In 1785 he succeeded Torbern Bergman, who had died the year before, as an associated member of the Societé Royal de Medecine in Paris. Unfortunately this message did not arrive in Köping until after Scheele's death. Likewise, he probably never received the information that he had been elected one of twelve foreign members of the Società Italiana in Verona, or that he had been made a member of the Society of Sciences in Erfurt.

Scheele had been healthy all his life, but in the autumn of 1785 he fell ill. He still continued with his research, and in February 1786 he sent his last paper to the Academy. In the spring the illness took a

serious turn, and he died on the 21st of May, only 43 years old. Three days before his death he married the widow of his predecessor who, during his 11 years in Köping had been his housekeeper and who now, once again, became the owner of the pharmacy.

Earlier, it was generally considered that the premature death of Scheele was due to his assiduous work and to his habit of smelling and tasting the compounds - for instance, chlorine, hydrogen sulphide, hydrogen arsenic, hydrocyanic acid, etc. - which he had prepared and whose toxicity he knew nothing about. The official cause of Scheele's death was tuberculosis but by studying the symptoms of his disease, a Swedish physician has come to the conclusion that he died of rheumatoid arthritis in combination with a heart disease. Scheele was buried at the Köping cemetary and on his gravestone we can look at a statue of a torch-carrying genius.

Although well-known as a chemist, Scheele is unknown as a person[16]. We do not even know what he looked like, because we have no picture of him. The portrait on the commemoration medal which the Academy of Sciences had coined in 1789 seems to have been drawn from memory, and the statue in Humlegården Park in Stockholm actually shows the son of the sculpturer John Börjeson. The statue in the market square in Köping is a free fantasy by the sculpturer Carl Milles and the stamps from 1942 certainly do not show a real portrait of Scheele. Regardless of his appearance, his achievements exist and will do so forever[17].

Fig. 5 - The statue of Scheele in Humlegården Park in Stockholm. Sculpturer: John Börjeson

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