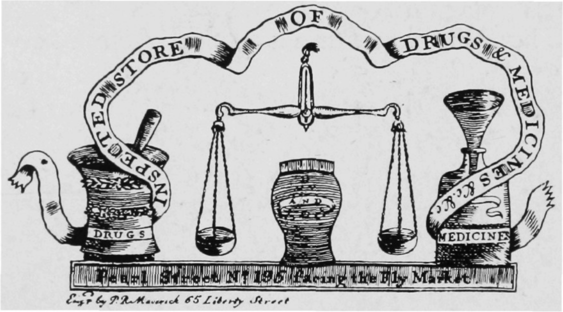
Pictorial Life History

of the

APOTHECARY CHEMIST

Carl Wilhelm Scheele



by

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TABLE OF CONTENTS

Preface

This booklet presents a collection of pictures pertaining to the life history of a great benefactor of mankind: the apothecary-chemist Carl Wilhelm Scheele. The pictures are preceded by a biographical sketch attempting not only to display but to explain the miracle of this man and his work. They are followed by a timetable of Scheele's experiments extracted from his letters and laboratory notes.

The intention is to give an idea of the world in which this great apothecary lived and worked and of the reaction to the man and his work both in and after his time. The legends accompanying the pictures are intended to be not only identifications but interpretations.

This small volume does not pretend to be or to replace a profound biography. However, it offers a survey of the most important data concerning the phenomenon Scheele and the phenomena of his investigations and discoveries. There is no real Scheele biography in the English language, no Scheele-Bible so to speak. The greater is the need for at least a Catechism. This booklet hopes to become the English Scheele-Catechism.

Most of the pictures are taken from the excellent Scheele biography edited by the Austrian pharmaceutical historian Otto Zekert and published between 1931 and 1935 by the *Gesellschaft für Geschichte der Pharmazie* (Society for the History of Pharmacy), of which the author of these lines was Director from its founding in 1926 until the German political upheaval in 1933. Some illustrations have been taken from other sources, e. g. Nordenskiöld's Scheele book published in 1892 and publications of the Swedish pharmacist S. Gullström.

Appearing on the occasion of the bicentennial of Scheele's birth, this booklet is destined to serve a threefold purpose:

THE MEMORY OF A GREAT MAN,

THE RESPECT FOR HONESTY IN WORK,

THE LOVE OF SCIENCE.

George Urdang

CARL WILHELM SCHEELE

Retail Pharmacist and One of the Greatest Chemists of All Time

Two hundred years ago, on December ninth or nineteenth 1742—the exact date is disputed—Carl Wilhelm Scheele was born. On the twenty first of May 1786 he died. Between these dates lies one of the most decisive periods of political history as well as of scientific history. As to political history the idea of democracy grew, more or less violently, into the realm of reality. As to scientific history the esoteric discussion of the abstract was superseded by the democratic search for the concrete. Theories were not to be imposed upon the facts any more but to be derived from them. The deductive and the inductive methods of research had finally changed their roles during this period.

It was this general situation which made the work of Scheele especially important. Here was a man to whom speculation meant nothing and the discovery and honest presentation of facts everything; one of the rare empirics whose special kind of genius enables them to put the right questions to the right subjects and to obtain the most surprising results in the most simple way.

Nothing in the early life of Carl Wilhelm Scheele indicated his later greatness. He was born in the then Swedish City of Stralsund (Pommerania) as the seventh of the eleven children of the brewer and later broker Joachim Christian Scheele and Margaretha Eleanora née Warnekros(s). Two years after his birth his father became bankrupt. There was neither much time nor much money to be devoted to the education of the boy whose shy and reserved behavior did not betray special talents anyway.

At the age of fourteen Carl Wilhelm Scheele left the private school which he had attended for eight years and decided to become a pharmacist. This decision proved to be of the greatest benefit to himself to pharmacy, to chemistry and finally to the world at large. It can be assumed that it was the example of his late older brother Johann Martin, born on February 14, 1734 and died on January 15, 1754, that influenced the boy's decision. This seems the more likely as Carl Wilhelm became an apprentice to the same man to whom his deceased brother had been apprenticed, i. e. to the apothecary Martin Andreas Bauch, the owner of the Pharmacy at the Unicorn in Gothenburg.

Now the latent talents and energies of the young man began to develop. He found himself surrounded by substances the real nature of which was not or merely incompletely known and which he could investigate and experiment with as he pleased, pushed by no one and responsible only to himself. His master, recognizing the unusual zeal of his apprentice, not only encouraged Scheele's scientific curiosity in granting him the material needed and as much time as possible, but in addition put his well equipped library at his apprentice's disposal. It was essentially the German apothecary Caspar Neumann's "*Praelec-*

tiones Chemicae" and the "*Cours de Chimie*" of the French pharmacist Lemery which young Scheele made subject of an intensive study and which formed the basis of his early experiments. It was during the eight years of his stay at Gothenburg (1757 to 1765) and the following three years of clerkship at the Pharmacy at the Spotted Eagle at Malmö (1765 to 1768), the lattter owned by the apothecary Peter Magnus Kjellström, that Scheele laid the groundwork for most of the discoveries which made him one of the greatest chemists of all time.

Anders Jahan Retzius, who became acquainted with Scheele at Malmö and who was the first real scientist to recognize and to take advantage of the genius in the young apothecary clerk, described his young friend in a letter written about twenty years later (1786) to Wilcke as follows:

"His [Scheele's] genius was given to him exclusively for physical science. He had absolutely no interest in any other. It is doubtless for this reason that his talents seemed to be poor if other matters were concerned. His memory was excellent. However, this too seemed only fitted to retain matters relating to chemistry. During his stay at Malmö he bought from Copenhagen as many books as his small pay enabled him to procure. These he read through once or twice. Then he remembered all that he desired to recall, and never again consulted the books. Without systematic training and with no inclination to generalize, he occupied himself mainly with experiments. From the time of his apprenticeship at Gothenburg, he had worked several years without plan and for no other purpose than to note phenomena; these he could remember excellently. Eleven years' continuous exercise in the art of experimenting had enabled him to collect such a store of facts that few could compare with him in this respect. In addition he had gained a readiness in devising and executing experiments such as is rarely seen. He made all kinds of experiments, so to say, pell-mell. This taught him what many a doctrinaire could never learn: since working by no formulated principles he observed much and discovered much that the doctrinaire would consider impossible, in as much it was opposed to his theories. I once persuaded him during his stay at Malmö to keep a journal of his experiments, and, on seeing it, I was amazed not only at the great number he made, but also at his extraordinary aptitude for the art."

A. E. Nordenskiöld in his book "Carl Wilhelm Scheele, *Nachgelassene Briefe und Aufzeichnungen*", Stockholm, 1892, in editing Scheele's "Laboratory Notes" made the following comment:

"These notes prove once more that the basic experiments for a large part of Scheele's great discoveries were already made at Gothenburg and Malmö, that already the apprentice had subjected to an exact investigation the entire material offered to a chemist in a pharmacy of his time achieving results which, if published immediately, would have made the years 1767-1770 a turning point in the development of chemistry."

The statements of Retzius and Nordenskiöld, the one based on personal knowledge and the other on the laboratory notes of the great apothecary and the perspective given by a distance of more than a century, are highly illuminating. They prove that the fact of Scheele's being a pharmacist was by no means incidental and negligible or even regrettable and detrimental to his research work as some of Scheele's biographers intimate. On the contrary, it was of greatest importance for the kind as well as for the amount of his achievements.

It may well be said that it was the good luck of Scheele and of chemistry that Scheele was, first and above all, a pharmacist. Here and only here a vast variety of subjects offered themselves to his scientific curiosity. Here and only here he was given the independence of work and conclusion which he needed. It was the apothecary Scheele who, encouraged by Bergman but carrying on his experiments quite independently, became interested in black magnesia which interest resulted in the recognition of the individuality of manganese and baryta and the discovery of chlorine. It was the apothecary to whom the problem of Prussian blue offered itself, leading to several important results among them the preparation of hydrocyanic acid, and it was finally the apothecary whose daily contact with tartar brought about the discovery of tartaric acid, the first of the chain of organic acids isolated by him. The red mercury oxide from which Scheele gained oxygen as early as in 1771/72 was a much used pharmaceutical substance and it was a typical pharmaceutical procedure, the preparation of lead-plaster, which lead Scheele to the observation and isolation of glycerin. It was the needs of pharmacy which caused Scheele to look for an inexpensive way of preparing phosphorus and for a more convenient method of preparing calomel.

The eleven years of pharmaceutical apprenticeship and clerkship in Gothenburg and Malmö mentioned above were followed by another seven years of clerkship, of which two years were served by Scheele in Stockholm at the Pharmacy at the Raven (1768 to 1770), owned by the apothecary Johan Scherenberg, and five in Uppsala at the Pharmacy at the Arms of Uppland (1770 to 1775) owned by the apothecary C. L. Lokk.

In all the pharmacies in which he worked, Scheele used every minute he could spare and every place he could find for his experiments. Thus at Stockholm the niche of a window had to serve his purpose. It is a significant proof of the genius of the young apothecary clerk that the peculiar situation of this place, far from hindering him, merely led him to observations which he scarcely would have made under other circumstances. It was here that Scheele discovered the difference in the reduction of silver chloride by different parts of the solar spectrum.

From the very beginning of his work in pharmacy and scientific research, young Scheele had a very critical attitude towards the wisdom to be found in the chemical literature of his time. P. M. Kjellström, his employer at Malmö, related that Scheele's usual comments while reading the chemical books procured by him were: "that may be", or "that is wrong", or "I have to check that". This critical attitude was, naturally, of special importance at a time in which there was no chemical terminology nor symbols precisely expressing the structure of the substances concerned. Scheele like his contemporaries still used the old pictorial symbols originating from the times of alchemy and based on astrological concepts. His work of correcting fanciful or misinterpreted statements would have secured for Scheele a place in the history of chemistry even if he would not have been the high ranking original discoverer that he was.

Hermann Kopp, in his history of chemistry, described the part played by Scheele in this respect as follows:

> "He was a watchful corrector of the errors of other chemists and in many cases it was his investigations that rightly defined and definitely disclosed the real nature of discoveries misinterpreted by their originators. Thus it was Scheele who proved that the supposed new metal found by Bergman in cold-short iron was merely a compound consisting of phosphorus and iron. When a French chemist announced that he had obtained a new acid from sodium phosphate, Scheele proved this supposed new acid, called pearl acid by its discoverer, to be sodium biphosphate. Similar corrections on his part contributed much to a more thorough examination and consideration of the results of chemical investigations. Many erroneous opinions of earlier times were likewise definitely disproved by Scheele."

Although pharmacy was undoubtedly the basis of Scheele's scientific work, his being a pharmacist did not prevent him from solving chemical problems not offered within the frame of his profession. Sweden is a land of mining. Her mountains contain valuable ores. Scheele refused to leave pharmacy for a position in industry. He did not go to the mountains, but the mountains came to him. In materials sent to him he discovered molybdic acid and tungstic acid and it was he who gave to industry the methods for the analytical separation of iron and manganese and for the decomposition of mineral silicates used for more than a century.

Until his early death at the age of only forty three years Scheele reported one discovery and observation after the other in such a rapid succession that his contemporaries were almost overwhelmed. Thus Lorenz v. Crell, the renowned founder and editor of Crell's *Chemische Annalen,* after having received the news about glycerin or oil-sweet *("Oelsuess")* as Scheele called it, wrote to Scheele on December 2, 1783 as follows: "I am wondering what more will be discovered by you! I dare to assume that no chemist is known to us who has ever made so many and so important findings. As soon as you have made another new discovery . . . please send it to me immediately without caring for postage. Your letters are not too expensive for me at any price."

This reverence paid Scheele by v. Crell was only one of the innumerable proofs of the high esteem in which the humble apothecary was held by his contemporaries. At the age of thirty two, still being an apothecary clerk and not yet having passed the Swedish apothecary examination, Scheele was made a member of the Swedish Royal Academy of Science and thus given the highest scientific distinction Sweden had to offer. It was no less a person than the great Torbern Bergman who took pride in initiating the new member and to welcome Scheele as follows:

"For several years I was witness of your unrivaled industry, of your special talent to elicit the secrets of nature by purposefully arranged experiments, and of the ingenious conclusions that you have drawn. Hence what can be more natural than the particular joy with which a man like me, loving his science ardently, sees you take a place of honor to which your merit and nothing else has paved the way for you."

In order to fully appreciate the real meaning of this tribute paid to Scheele by this man on this occasion one has to bear in mind that at this time, the triumphant statements of Lavoisier and the era introduced by them being still a matter of the future, Bergman's position as dean of the contemporary chemists and arbiter in matters chemical was scarcely disputed. It had been only a few years ago that the advice of Bergman had caused the same Academy of Science, that now bestowed its membership upon Scheele, to refuse the first papers the young apothecary clerk had presented for its memoirs. The somewhat clumsy style of Scheele's manuscripts had been repugnant to the feelings of the elegant and eloquent Bergman. In the meantime Bergman had found the way from the outside to the inside of this rare man, and there developed a cooperation unusual in its extent as well as in its results. Scheele's old friend Retzius, knowing both parties very well, characterized the relations between Scheele and Bergman as follows:

"It is hard to say which of them, Scheele or Bergman, was *Docens* (the teacher) or *Discens* (the disciple); for without any doubt Bergman owed the greatest part of his practical knowledge to Scheele, while it was due to the influence of Bergman that Scheele's knowledge was in his later years clearer than in the earlier ones."

After the death of Bergman, J. C. Wilcke, then Secretary of the Swedish Royal Academy of Science, wrote in a letter to Scheele under the date of August 9, 1784 as follows: "Since we lost Bergman, it is you in whom we put the greatest confidence that you will keep up our [Sweden's and the academy's] reputation as to chemistry."

The authority which Scheele enjoyed was so great, and his honesty and simplicity of character so obvious and disarming that none of the usual scientific jealousies and quarrels ever touched him. When his book on air and fire, due to the negligence of his publisher, appeared so late that some of his statements concerning oxygen etc. were in the meantime made and published by other authors, nobody dared to raise the question of plagiarism. When three years later the English edition appeared which, provided with notes of the English chemists working on the same problem, presented in addition to the translation of the original a profound discussion of the subject concerned, the controversy was conducted with the utmost respect. Informing Scheele of the English edition and the fact that his conclusions were disputed in the book, the translator, Johan Reinhold Forster, in a letter of September 15, 1780, paid high tribute to Scheele's sagacity, knowledge and ingenuity and concluded as follows: "Your adversaries are people who do not lack courtesy, kindness, moral character, nor knowledge; hence a discussion, nobly carried on, cannot be anything but useful to the realm of truth." Such was the atmosphere Scheele forced upon everyone, even upon his adversaries.

Naturally, the question as to the priority of the discovery of oxygen has been discussed again and again. It was not until 1892 that the publication of Scheele's correspondence and laboratory notes, presented to the world by the Swedish naturalist and arctic explorer A. E. Nordenskiöld, definitely proved that prior to 1773, that is at least a year before the date of Priestley's discovery, Scheele had prepared oxygen from the carbonates of silver and mercury, from mercuric oxide, nitre and magnesium nitrate, and by distillation of a mixture of manganese oxide and arsenic acid.

According to Rosenthaler *(Ber. Deutsche Pharm. Ges., 1904)* it was Scheele who for the first time consciously showed that it is possible and necessary to prepare systematically the plant constituents as chemical individuals and that, for this reason, "Scheele and no one else has to be regarded as the founder of modern plant chemistry." Since Scheele, in 1783, prepared hydrocyanic acid from coal, ammonium chloride and potash, Ferchl-Süssenguth in their *"Kurzgeschichte der Chemie"*, Mittenwald, 1936, gave to him and not to Wöhler the credit to have been the first to perform an organic synthesis. Scheele employed and in 1782 recommended sterilization, and his observation that different parts of the solar spectrum influence the decomposition of silver chloride in very different degrees (1775) has been considered the beginning of spectral photography.

There cannot be any doubt that Scheele knew exactly what pharmacy meant to him and his work. He often stated in his letters that his pharmaceutical duties did not leave him much time for his experiments. But in almost all cases these statements represented apologies for not having produced more. They were not intended to be nor could they be considered as complaints. Scheele left the Pharmacy at the Raven in Stockholm because there his work in the prescription department required his time and strength to such an extent that it threatened to stop his research almost completely. However, he never even thought of leaving the profession of pharmacy. He knew that he had to pay for his independence and that the price was by no means too high. There was scarcely a happier man in the world than the apothecary clerk Scheele when in the end of 1774 he was offered the management of the only pharmacy in the small town of Köping.

"O, how happy I am," he wrote to Gahn in a letter of December 26, 1774, "no worry any more as to my board and room; no worry as to my pharmaceutical work and the manufacture of the preparations needed in the store—for that means only a play to me. However, to explain new phenomena, that will be what I have to worry about, and how glad is the experimenter if he finds what he was so eagerly searching for,—a pleasure which makes his heart leap with joy."

Scheele had scarcely become warm in his position as manager of the pharmacy in Köping when his tenancy there was seriously endangered. A wealthy apothecary offered the widow of the deceased owner such a profitable price that she decided to accept it and to sell the store. What then happened is highly significant of the esteem in which Scheele was held as well as of his inner relation to pharmacy. A. E. Nordenskiöld's report about this episode in Scheele's life reads as follows:

"Gahn offered Scheele a position as "collaborator" at Falun, in all probability to secure Scheele's advice in matters of a chemico-technical nature for the great industrial plants of this place. Bergman wanted him back at Uppsala. At the initiative of other friends of Scheele, among them Linné, Wargentin, the Secretary of the Royal Academy of Science, and the brothers Bergius, who were very influential in the scientific circles of Stockholm, the great Swedish industrialist P. Alströmer offered Scheele the pharmacy at Alingsas with an appropriate laboratory under favorable conditions. It was planned to make him manager of a distillery or, the most appropriate plan of all, to create for him the position as "*Chemicus Regius*" (Royal chemist) in the capital. Scheele received furthermore very alluring offers from foreign countries. D'Alembert, in a letter of December 15, 1775, suggested to Frederick II of Prussia that he offer Scheele a position at Berlin . . . An offer to go to England with an annual salary of £300 is mentioned in the biographical sketch of L. v. Crell. However, all these offers were turned down by Scheele. He told friends that he would like most to stay at Köping and that he had promised to go back to his previous employer at Uppsala, the apothecary Lokk, if he should be forced to leave Köping. . .

In the short time of his stay at Köping Scheele had won the confidence of his customers to such an extent that the owners of the estates in the vicinity of the town used their political influence to procure for him the permission to open a second pharmacy in Köping. His fellow citizens publicly pronounced that they did not want any other apothecary in their town but Scheele. They were afraid of being blamed later on for having neglected the interest as well as the honor of their town if they did not make every effort to keep Scheele. In consequence of these events the sale of the pharmacy was cancelled, and from now on nothing prevented Scheele throughout his life from devoting to his research all the time which his occupation as an apothecary left to him."

Scheele never disappointed the confidence of his fellow citizens. Although his research meant everything to him, his experiments had to wait until his pharmaceutical work was taken care of. In a letter to J. C. Wilcke of March 18, 1784 he wrote: "I am doing my chemical research only as a sideline in order not to neglect my duty in my apothecary shop." It may well be assumed that to some extent Scheele liked if not even needed the change between the service to mankind in his laboratory and that devoted to his suffering fellow citizens in his pharmacy. Although the Swedish Royal Academy of Science supported the scientific work of Scheele with an annual stipend, it was essentially the income drawn from his pharmacy which enabled him not only to save a small fortune but, in 1782, to replace his old laboratory by a new one. At the time of Scheele's death the laboratory of the pharmacy at Köping was said to have been excellently equipped.

Scheele took undoubted pride in his being a pharmacist. It was not until 1777 that he found time to go to Stockholm and to take the examination as a Swedish apothecary. Under the presidency of the physician in ordinary to the King of Sweden, Abraham Baeck, the Royal College of Physicians, members of which with the assistance of two apothecaries formed the examination board, made the examination an act of reverence to the famous candidate. After having received his certificate, Scheele designated himself an apothecary whenever he signed an official document. It can be assumed that he, for his lecture before the Royal Academy of Science on the occasion of his initiation, deliberately chose a pharmaceutical topic, the presentation of his new process of preparing calomel. The search for this process as well as for Scheele's new method of preparing algaroth powder was avowedly caused by his desire to present his colleagues with methods less harmful to their respiratory organs than the old ones. Scheele knew of the special dangers which the profession of pharmacy holds in store for its adept from his own painful experience. In 1785, one year before his death, he complained about his gout. "The worst is", he wrote, "that sometimes I am suffering from hyperchondria. However, perhaps there is no apothecary without gout."

Scheele was so exclusively devoted to his science on the one hand and to his pharmaceutical service to his fellow citizens on the other that he literally had no private life. In his entire correspondence there is, besides not very frequent letters to his parents and brothers, hardly one note which is not devoted or does not refer to his work. There was never a woman in his life. The widow of the preceding owner of the pharmacy at Köping took care of his household for ten years. He married her three days before his death in order to secure for her the inheritance of his small fortune. In a letter to the Secretary of the Royal Academy of Science written shortly after Scheele's death, Mrs. Scheele stressed the fact that she had "honored Scheele's memory through the most honorable funeral that the town had ever seen." The pompous silver shield on Scheele's coffin proves what she meant by that.

Carl Wilhelm Scheele belongs to the very few great men whose appreciation by their contemporaries has been fully confirmed by posterity and has remained unchanged in its kind as well as in its extent through the ages. Of the honors bestowed upon him during his lifetime his early membership in the Swedish Royal Academy of Science has been mentioned. Later on the Honorary Membership of the following scientific societies was bestowed upon him: *Gesellschaft Naturforschender Freunde zu Berlin* (1778), *Regia Scientiarum Taurinensis Academia* (1784), *Societa Italiana* at Verona (1785), *Société Royale de Medecine* at Paris (1785), *Churmainzische Gesellschaft der Wissenschaften* at Erfurt (1785).

After the death of Scheele medals in his honor were coined by the Swedish Royal Academy of Science in 1789 and in 1827, the Swedish Association of Apothecaries in 1892 and the twelfth International Congress of Physiologists, held at Stockholm in 1926. Monuments and busts of C. W. Scheele remind of the great apothecary and his work in Stockholm, Köping and Stralsund, and on the occasion of the bicentennial of his birth, on December 19, 1942, Sweden released two stamps with his portrait and his signature.

The first biography of Scheele was the oration delivered by C. G. Sjösten before the Royal Academy of Science at Stockholm on October 14, 1799 and published in the annals of the Academy in 1801. This oration was based on the material collected by J. C. Wilcke and it formed on its part the basis of all later biographies of Scheele. In 1886 E. A. Flückiger's article on Scheele, containing a detailed survey of Scheele's achievements, appeared in the *Archiv der Pharmacie.* In 1892 A. E. Nordenskiöld published the letters and laboratory notes of Scheele. Between 1931 and 1935 the *Gesellschaft für Geschichte der Pharmazie* published Otto Zekert's excellent Scheele biography, the author of which used and completed the work of Nordenskiöld. The number of biographical essays concerning Scheele is legion. In the English language the most remarkable one is that contained in T. E. Thorpe's "Essays in Historical Chemistry" (1894). There is, naturally, no chemical text containing historical notes, no book on the history of chemistry that does not mention Scheele. However, the fact of Scheele's being a pharmacist has in almost all cases where non pharmacists were the authors, at best been given cursory treatment. As far as I know, its real meaning to Scheele and his scientific work has been properly interpreted by only two of the many authors of biographical sketches of Scheele, the French pharmacist M. Cap *(Journal de Pharmacie et de Chimie*, 1863) and the Austrian Otto Zekert mentioned before. The usual attitude towards the pharmacist Scheele is characterized by the attempt to present him as an exceptional case belonging to pharmacy by mere chance not by destiny.

It seems necessary in the interest of historical truth, to draw attention to the fact that just in the time of Scheele pharmacy was looked upon as the foster-mother, if not even the mother, of scientific chemistry. Within the immediate zone of Scheele's life and work the following facts present themselves:

As mentioned before it was primarily the books of two pharmacists, the Frenchman Lemery and the German Caspar Neumann, which opened to the young apprentice the doors to scientific chemistry. Of the four owners of pharmacies in which Scheele worked as an apprentice and as a clerk, three, i. e. M. A. Bauch in Gothenburg, P. M. Kjellström in Malmö and C. L. Lokk in Uppsala, were well known for their scientific effort. In his "Westgothlandish Journey" Linné mentions Bauch's collection of natural curiosities, and Kjellström as well as Lokk were renowned experts in the cultivation of medicinal plants. When Scheele in his experiments concerning hydrofluoric acid obtained misleading results because of his using a glass retort for the distillation of fluorspar with sulfuric acid, it was the apothecary Johann C. F. Meyer, owner of a pharmacy in Stettin, who advised him to use lead apparatus for this kind of work.

The man whom Scheele was supposed to succeed as chemist of the Royal Prussian Academy of Science, Andreas Sigismund Marggraff, the famous discoverer of sugar in the beet, had started his career as a pharmacist. The man who, in 1793, gave to the chemical world the first German collection of the publications of Scheele was S. F. Hermbstädt, practising pharmacist at Berlin and simultaneously professor of chemistry and pharmacy. The man to whom Hermbstädt dedicated the book, finally, was likewise a practising pharmacist teaching simultaneously chemistry and conducting scientific research, the discoverer of the elements uranium and zirconium and of a host of other substances, Martin Heinrich Klaproth. In addressing Klaproth in the preface of the book, Hermbstädt explained this dedication as follows: "Who is the man who could deny that you are the only one able to make good the loss of Scheele! Was it not the chemists of the whole of Europe that admitted this fact to you?" Hermbstädt based the publication of Scheele's collected treatises on subscriptions. It is significant of the scientific interest among the apothecaries of this period that of the 150 subscribers listed not less than 121, i. e. about eighty percent, called themselves or are known to have been pharmacists.

The profit drawn by a peaceful world from the discoveries of C. W. Scheele has been enormous. The work of this "corner druggist" has become a corner stone in the edifice of modern civilization. The bleaching and the laundry industry and wide fields of chemical disinfection among them that of water purification are inconceivable without chlorine. The fruit acids discovered by Scheele are of highest importance for the modern foodstuff and beverage industries. Tungsten and molybdenum, to the discovery of which Scheele paved the way, are indispensable in modern steel industry, and glycerin, finally, belongs to our daily life commodities used for a multitude of purposes and in many industries.

In 1930 the Association of American Soap and Glycerin Producers sent to the Swedish Crown Prince a message felicitating him on the discovery of glycerin by a Swedish citizen. Today it would be up to the manufacturers of explosives using nitro-glycerin as the basis of their deadly products to do the same.

In 1892 the committee for the erection of a Scheele monument at Stockholm stated in a public pronouncement that "Scheele contributed more to the development of the era in which we are living than diplomatic negotiations and pitched battles."

At the present time, fifty years later, we are once more in the midst of pitched battle. However, honoring nevertheless the memory of the great men of science and peaceful progress, the memory of men like Scheele, we are reminding the world and ourselves of what we are fighting for.

C. G. Sjösten, then Vice President of the Swedish Royal Academy of Science expressed his belief in the immortality of Scheele's work in a lecture delivered before the Academy in 1789 as follows:

"Although Scheele like a blazing comet passed our horizon with great velocity, disappearing after having scarcely been observed, yet the splendor of his genius has incited the attention of all, has spread light on the broad field of chemistry, has paved the way for others, and gained for himself an imperishable monument in the memory of the chemists, the naturalists and all who love science. His name cannot be forgotten as long as fire and air remind the mortals of the discoveries, given to them with regard to these substances by Scheele, and his honor, based on his own merit, resists all change of time."

The Achievements of Carl Wilhelm Scheele

T. E. Thorpe, in his "Essays in Historical Chemistry" (1894), describes the achievements of C. W. Scheele as follows.*

"We owe to Scheele our first knowledge of chlorine (1774) and of the individuality of manganese (1773) and baryta (1771-1772).

He was an independent discoverer of oxygen (prior to 1773), ammonia (1770), and hydrochloric acid gas (1770).

He discovered also

hydrofluoric (1771)
nitro-sulphonic (1766)
molybdic (1778) acids
tungstic (1778)
arsenic (1771-1772)

among the inorganic acids.

and

lactic (1780)
gallic (1770)
pyrogallic (1770)
oxalic (1770)
citric (1784) acids
tartaric (before 1768)
malic (1784)
mucic (1780)
uric (1776)

among the organic acids.

He isolated glycerin (1783) and milk-sugar (1780); determined the nature of microcosmic salt (sodium ammonium phosphate, 1774), borax (1768), and Prussian blue (ferric ferro cyanide, 1783); prepared hydrocyanic acid (1783).

He demonstrated that plumbago is nothing but carbon associated with more or less iron (1779);

ascertained the chemical nature of sulphuretted hydrogen (1768);

discovered arsenetted hydrogen (1775) and the green arsenical pigment which is associated with his name (Scheele's Green or copper arsenite, 1777);

* The dates added in brackets are not given by Thorpe but furnished by the editor on the basis of Nordenskiöld's publication of Scheele's correspondence and laboratory notes (1892) and of the collection of Scheele's publications edited by Hermbstädt in 1793.

He invented new processes for preparing ether (1770),
powder of algaroth (1778),
(antimony of oxychloride)
phosphorus (1770),
calomel (1774),
magnesia alba (1776).

His services to quantitative chemistry included the discovery of ferrous ammonium sulphate (1777), and of the methods still in use for the analytical separation of iron and manganese (1777), and for the decomposition of mineral silicates by fusion with alkaline carbonates (1786)."

Thorpe's list, comprehensive as it appears, is not complete. Scheele furthermore invented a new process for preparing benzoic acid, his so called wet method, (1775), discovered nitrous acid (1767), fluosilicic acid (1773) and benzoic ester (1780).

It is of importance that it was Scheele's discovery of molybdic acid in 1778 which led to the isolation of metallic molybdenum by Hjelm (1782), and his discovery of tungstic acid in 1781 paved the way for the isolation of metallic tungsten by the Spanish chemists D'Elhuyar (1783). In a letter to J. C. Wilcke of August 19, 1785 Scheele expressed his delight about the fact that his experiments on calcium tungstate (Scheelite), molybdite, and black manganese have led other chemists to the discovery of new metals.

As to the much discussed priority of the discovery of oxygen Thorpe concludes from the correspondence and laboratory memoranda of Scheele published by Nordenskiöld in 1892 that "prior to 1773, that is at least a year before the date of Priestley's discovery, Scheele had prepared oxygen from the carbonates of silver and mercury, from mercuric oxide, nitre and magnesium nitrate, and by the distillation of a mixture of manganese oxide and arsenic acid."

Scheele was the first to artificially prepare an organic plantconstituent in obtaining oxalic acid upon oxidation of sugar with nitric acid (1776) and transforming this acid into its calciumsalt.

According to Ferchl-Süssenguth, *Kurzgeschichte der Chemie,* Mittenwald, 1936, the first organic elementary synthesis originates "contrary to thousandfold assertions" not from Wöhler but from Scheele who in 1783 prepared hydrocyanic acid from coal, ammonium chloride and potash.

Scheele's advice to fill vinegar in bottles and to boil these bottles in a water bath for about one hour in order to prevent the liquid from fermentation and destruction (1782) means the recognition and the employment of the principles of sterilization, almost a century later explained and brought into general use by Pasteur.

Scheele's observation that different parts of the solar spectrum influence the decomposition of silver chloride in very different degrees (1775) has been considered the beginning of spectral photography.

Pictures
Pertaining to
the Life and Work
of
CARL WILHELM SCHEELE

THE CITY of STRALSUND
The Birthplace of C. W. Scheele
in 1740

In the eighteenth century Stralsund belonged to Sweden.

The House where Carl Wilhelm Scheele was Born at Stralsund, Dec, 19, 1742

The picture shows the house as it was in 1874.

The City of Gothenburg about 1750

From 1757 to 1765 C. W. Scheele was employed first as an apprentice and then as a clerk in the pharmacy of the apothecary Martin Andreas Bauch (Pharmacy at the Unicorn) at Gothenburg. The house designated by an asterisk lodged the pharmacy.

Bauch placed his remarkable library at the disposal of his unusual apprentice. It was especially the *"Praelectiones Chemicae"* of the German apothecary Caspar Neumann and the *"Cours de Chimie"* of the French pharmacist Lemery which young Scheele made subject of an intensive study and which formed the basis of his early experiments.

"Pharmacy at the Raven" at Stockholm

In this pharmacy which was owned by the apothecary Johann Scharenberg, C. W. Scheele worked as an apothecary clerk from 1768 to 1770. He left this position after only two years because the very comprehensive prescription business did not leave him time for his experimental work.

"Pharmacy at the Arms of Uppland" at Uppland

In this pharmacy which later changed its name to "Pharmacy at the Lion", Scheele worked as a clerk from 1770 to 1775. The owner of the pharmacy, Christian Ludwig Lokk, himself a man of scientific ambition and achievement, gave the young experimenter all opportunity and whatever time could be spared for his work. Nevertheless Scheele wrote to J. G. Gahn: "Only one day in eight I am able to experiment. All the other time I must devote to pharmaceutical service in the dispensing room."

It was here that Scheele came in contact with the great Swedish scientists J. G. Gahn, Carl Linné and, above all, Torbern Bergman.

Scheele's Pharmacy at Köping

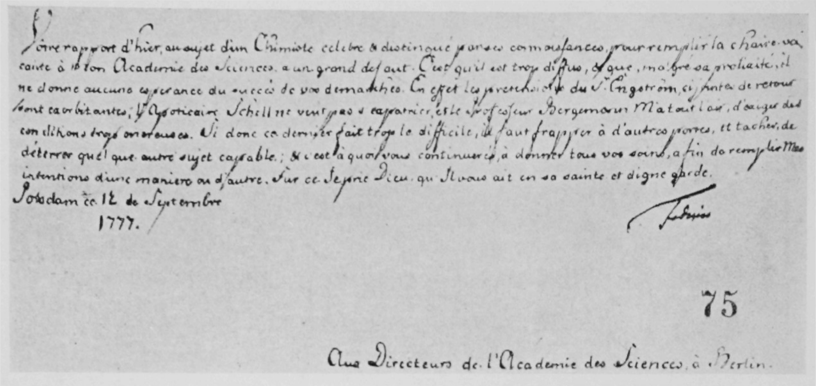
It was this modest building that housed the apothecary shop in which Carl Wilhelm Scheele served his fellow citizen in the small Swedish town of Köping. The laboratory in which he served the world, was until 1782 still more modest—a wooden barn in the courtyard.

Original Fixtures and Containers of Scheele's Pharmacy

The Nordisk Museum at Stockholm preserves this corner of Scheele's pharmacy, so representative of the fixtures and drug containers of a typical European pharmacy of the eighteenth century.

Pharmacy at Köping, Interior about 1850

Although fixtures and containers had undergone changes since the time of Scheele, the character and the atmosphere of the pharmacy had remained unchanged at the time of this picture.



Votre rapport d'hier, au sujet d'un Chimiste celebre & distingué par ses connoissances, pour remplir la chaire vacante à votre Academie des Sciences, a un grand defaut. C'est qu'il est trop diffus, & que, malgré sa prolixité, il ne donne aucune esperance du succès de vos demarches. En effet les pretensions du Sr. Engstrom, ci-jointes de retour sont exorbitantes; l'Apoticaire Schell ne veut pas s'expatrier, et le Professeur Bergmann m'a tout l'air, d'exiger des conditions trop onereuses. Si donc ce dernier fait trop le difficile, il faut frapper à d'autres portes, et tacher de déterrer quelque autre sujet capable; & c'est à quoi vous continuerés à donner tous vos soins, afin de remplir mes intentions d'une maniere ou d'autre. Sur ce Je prie Dieu, qu'Il vous ait en sa sainte et digne garde.

Potsdam ce 12 de Septembre
1777.

Federic

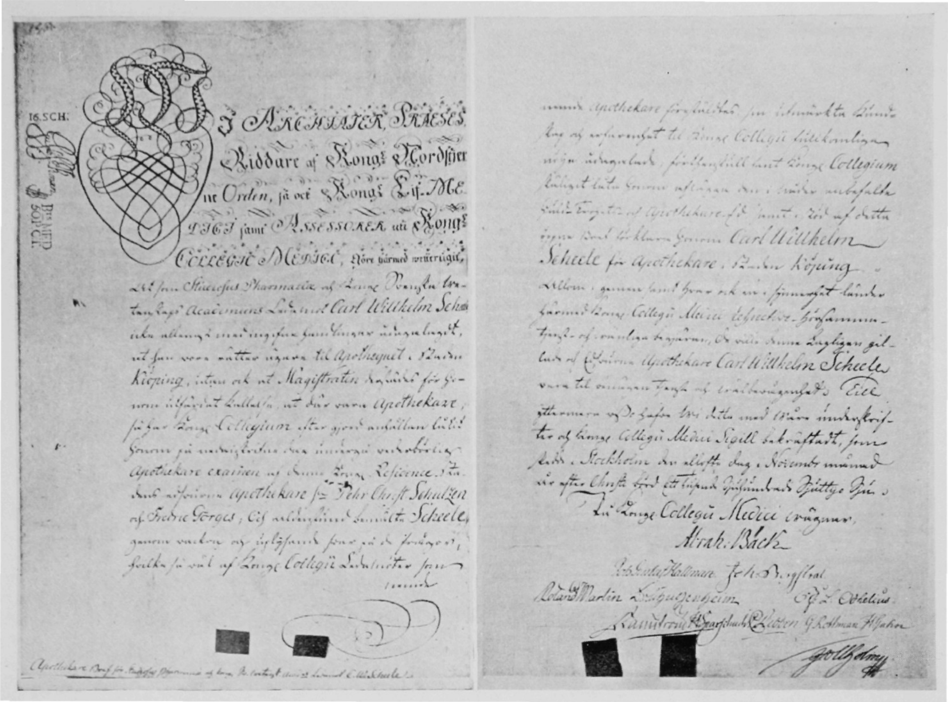
75

Aux Directeurs de l'Academie des Sciences, à Berlin.

Letter of King Frederick The Great of Prussia concerning C. W. Scheele

In this letter to the directors of the Royal Prussian Academy of Science at Berlin the King refers to Scheele's refusal of the offer to become a chemist at the Academy.

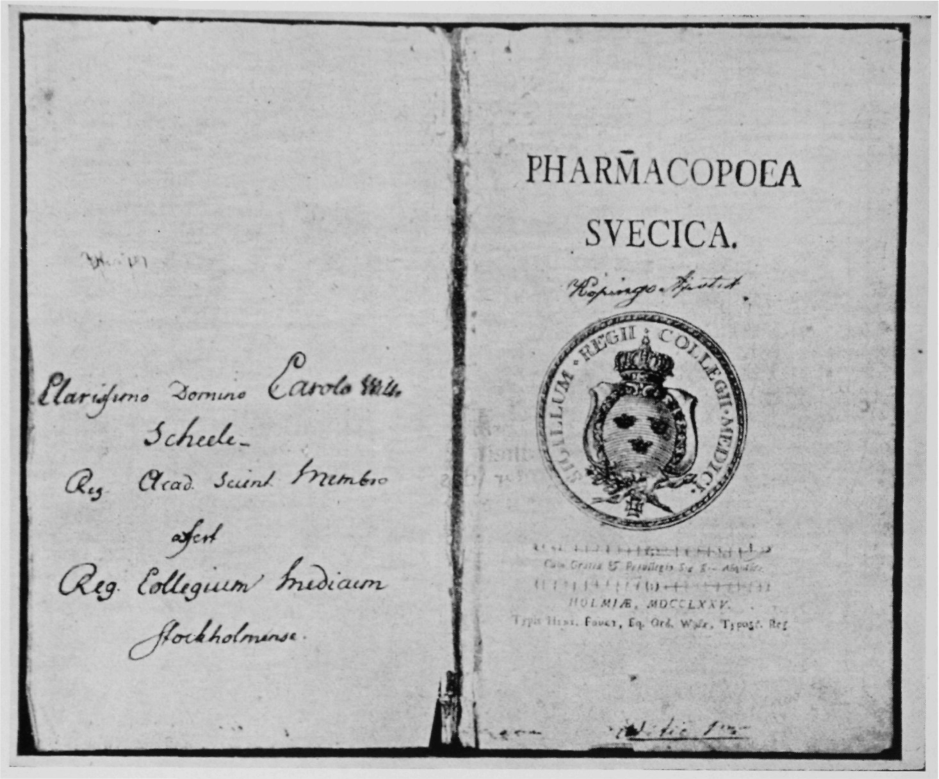
Predicting Scheele's refusal, the Prussian Ambassador to Sweden, Count Nostiz, under the date of July 23, 1777 had reported as follows: "Mr. Schell (Scheele) is an apothecary in a provincial town. He owes his chemical knowledge exclusively to long endeavor and rich experience, gaining for him real merit and resulting in a theory which is absolutely his own. His indifference to all the advantages that have been offered to him in order to exploit his chemical knowledge by several undertakings in the capital, makes me fear that it will be difficult to induce him to leave this country."



Scheele's Certificate as an "APOTHEKARE"

Although in 1777 a man of world fame, and for more than two years a member of the Swedish Royal Academy of Science, Scheele had to pass the examination as a Swedish apothecary in order to be permitted to operate his pharmacy at Köping.

The Royal Collegium Medicum functioning as examination board under the presidency of the Royal Archiater Abraham Baeck, made this examination an act of reverence to the candidate.



Clarissimo Domino Carolo Wilh.
Scheele
Reg. Acad. Scient. Membro
affert
Reg. Collegium Medicum
Stockholmense.

PHARMACOPOEA
SVECICA.
Kopings Apotek.

HOLMIÆ, MDCCLXXV.
Typis Henr. Fougt, Eq. Ord. Wasæ, Typogr. Reg.

Pharmacopoea Svecica 1775

The Royal College of Medicine at Stockholm presented Scheele with this copy of the Swedish pharmacopoeia of 1775. It is significant that the dedication is devoted to the "Illustrious Carl Wilhelm Scheele, Esquire, Member of the Royal Academy of Science", while in Scheele's own handwriting the book was given the simple ownership sign "Kopings Apotek".

In 1777 Scheele was asked for co-operation in the preparation of the planned new edition of the pharmacopoeia and offered the remuneration of his expenses for all experiments required. It is of interest that no less a person than the great Linné also co-operated in the preparation of this pharmacopoeia.

Chemical Symbols used by C. W. Scheele

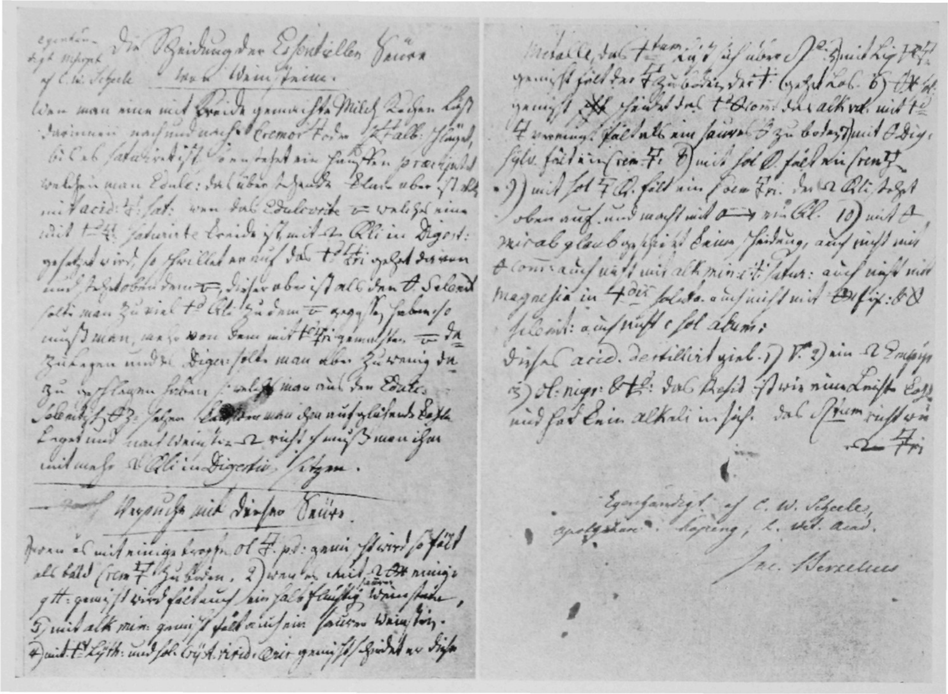
(Facsimile out of H. T. Scheffer's
"Chemiske Föreläsningar",
edited by Torbern Bergman, Uppsala 1775)

Sal in genere
acidum; c. concentratum, d. dilutum
Acidum minerale
Acidum Vitrioli
c. concentratum, d. dilutum
Acidum Nitri; a. phlogiſticatum
Aqua fortis
Acidum Salis. a. dephlogiſticatum
Aqua Regis
Acidum fluoris minerale
Acidum arſenici
Acidum Vegetabile
Acidum tartari
Acidum Sacchari
Acetum
Acidum animale
Acidum urinæ, phosphori
Acidum Formicarum
Acidum aereum; atmoſphæricum
Sal alcalinus
Sal alc. purus (Cauſticus)
Alcali fixum vegetabile
Alcali fixum minerale
Alcali volatile

Sal neutralis
Nitrum
Sal communis
Tartarus; r. ruber, a. albus; p. purus
Borax
Sal ammoniacus
Sal medius terreſtris cum acido
Magneſia vitriolata (Sal amarum Anglic.)
Alumen
Sal medius terreſtris cum alcali
Alcali volatile magneſia ſaturatum
Sal medius metallicus cum acido
Vitriolum cupri (v. Coeruleum)
Vitriolum ferri (v. viride)
Vitriolum zinci (v. album)
Luna nitrata (cryſtalli lunæ)
Mercurius Sublimatus corroſivus
Mercurius præcipitatus albus
Plumbum acetatum (Saccharum ſaturni)
Cuprum acetatum, cupr. acet. purum
Aurum regaliſatum
Sal medius metallicus cum alcali
Alcali volatile cupro ſaturatum
Sal ſedativus

Terra.
Lapis
Arena
Calx: p. pura (uſtulata.)
Calx vitriolata (ſelenites. gypſum)
Terra ponderoſa
Magneſia
Argilla
Terra Silicea
Cryſtallus
Vitrum
Fel vitri
Minera
m. Calx metallica
Aurum fulminans
Turpetum minerale
Arſenicum album
Vitrum plumbi
Magnes
Metallum
Cinis
Urina
Aqua
Aer; n. nudus
Ignis
Phlogiſton
Sulphur
Phosphorus
Pyrophorus
Carbo
Oleum unguinoſum
Oleum empyreumaticum
Oleum eſſentiale
Æther
Spiritus vini R.ſ. rectificatiſſimus
Alcali phlogiſticatum
Hepar alcalinum, Hepar terr. pond.
Hepar calcis, Hepar magneſiæ

Reſina
Gummi: gummi reſina
Metallum ſulphuratum
Mercurius ſulphuratus (cinnabaris)
Aurum (Sol)
Platina
Argentum (Luna)
Hydrargyrus (Mercurius)
Plumbum (Saturnus)
Cuprum (Venus)
Ferrum (Mars)
Stannum (Jupiter)
Viſmutum
Niccolum
Arſenicum
Cobaltum
Zincum
Antimonium
Magneſium
Retorta
Recipiens
Cucurbita: Alembicus
Crucibulum
re. Evaporare; tio Evaporatio
re Digerere; tio Digeſtio
re. Coquere, ebullire
re Deſtillare
re Incinerare
re. Calcinare
re. Sublimare, Sublimatum
re Pulveriſare; pulvis
re. Solvere, tio. Solutio
re. Præcipitare, Præcipitatum
re. Fundere, io fuſio
Reſiduum, Caput mortuum
Menſis
Dies, Nox; Nyctemeron
Hora.



Manuscript of C. W. Scheele dealing with "The Separation of the Essential Acid out of Tartar"

This manuscript dealing with the discovery of tartaric acid was in the possession of the famous Swedish chemist Jöns Jacob Berzelius (1779-1848), the creator of modern chemical symbols.

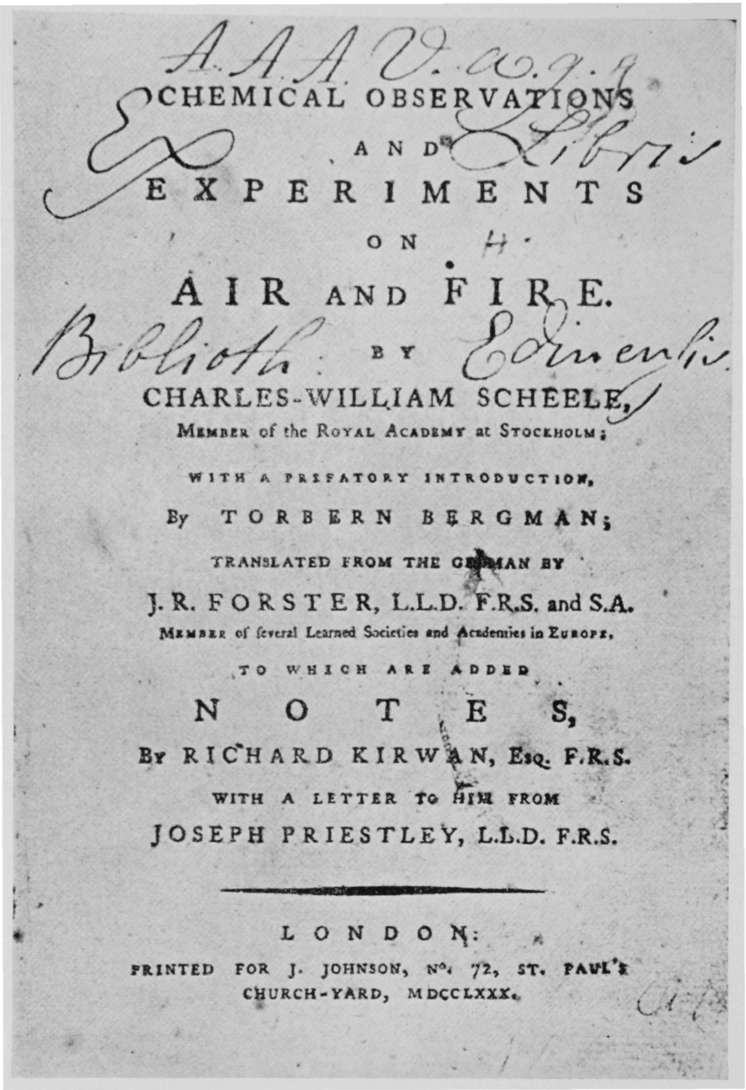
How much Berzelius cherished this manuscript and its author becomes evident from the fact that he expressly stated and confirmed by his signature its being written "by C. W. Scheele, Apothecary, Köping, Member of the Academy of Science, with his own hand."

Carl Wilhelm Scheele's
d. Königl. Schwed. Acad. d. Wiſſenſchaft. Mitgliedes,
Chemiſche Abhandlung
von der
Luft und dem Feuer.
Nebſt einem Vorbericht
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.

First Edition of Scheele's Treatise of his Discovery of Oxygen

The manuscript was delivered to the printer in 1775. It is not known why it took the printer almost two years to publish the book. Known is, however, that Scheele repeatedly complained about the negligence of the printer. In a letter to Bergman of August 30, 1776 he wrote that, if later people should think he had taken advantage of findings of other authors published in the meantime, "I would have to thank Swederus (the printer) for all that."



Ex Libris

CHEMICAL OBSERVATIONS
AND
EXPERIMENTS
ON
AIR AND FIRE.

Biblioth: Edinensis

BY
CHARLES-WILLIAM SCHEELE,
MEMBER of the ROYAL ACADEMY at STOCKHOLM;
WITH A PREFATORY INTRODUCTION,
By TORBERN BERGMAN;
TRANSLATED FROM THE GERMAN BY
J. R. FORSTER, L.L.D. F.R.S. and S.A.
MEMBER of ſeveral Learned Societies and Academies in EUROPE,
TO WHICH ARE ADDED
NOTES,
BY RICHARD KIRWAN, ESQ. F.R.S.
WITH A LETTER TO HIM FROM
JOSEPH PRIESTLEY, L.L.D. F.R.S.

LONDON:
PRINTED FOR J. JOHNSON, No. 72, ST. PAUL'S
CHURCH-YARD, MDCCLXXX.

English Edition of Scheele's Treatise concerning his Discovery of Oxygen

This English edition of Scheele's famous treatise, appearing three years after the publication of the original, was far more than a mere translation. The notes added by the English chemists gave this edition the character of a profound discussion by the best experts.

In a letter to Scheele, the translator, J. R. Forster, wrote on September 15, 1780 as follows: "Your adversaries are people who do not lack courtesy, kindness, moral character, nor knowledge; hence a discussion, nobly carried on, cannot be anything but useful to the realm of truth."

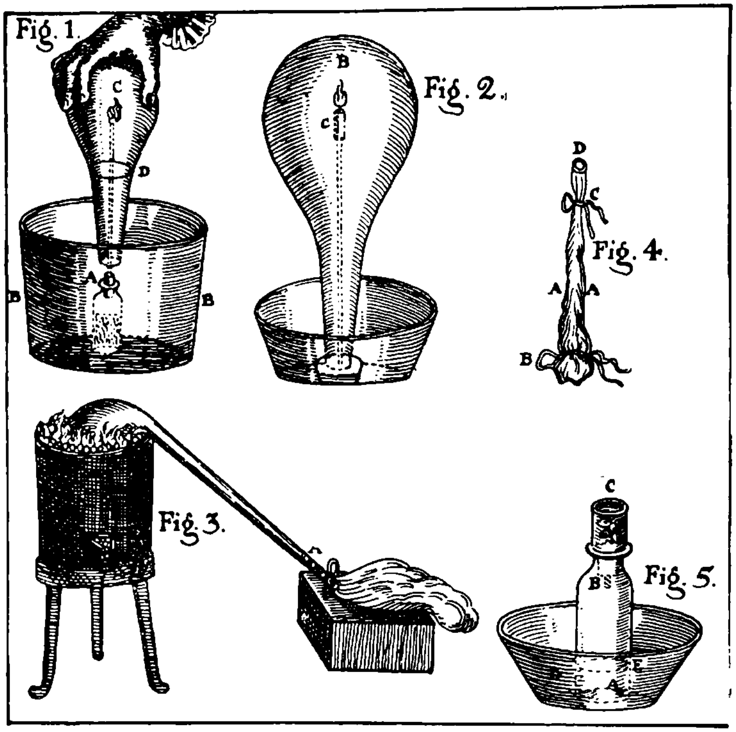


Table of Apparatus in back of Scheele's Treatise on Air and Fire

"My arrangements and vessels are the simplest that one can possibly have: flasks, retorts, bottles, glasses and ox bladders are the things which I employ." (§30)

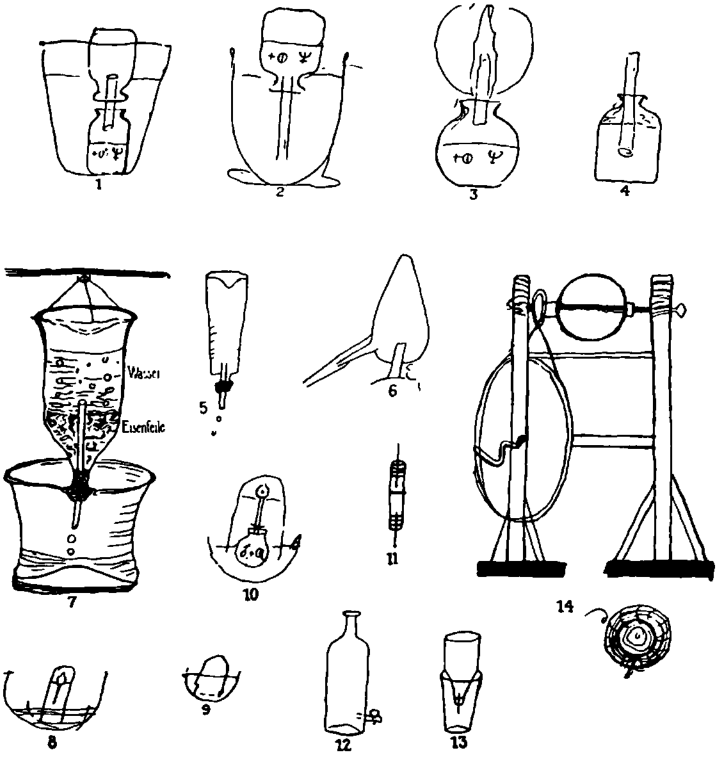
Fig. 1: The bottle A contained ironfilings and diluted sulfuric acid, and the vessel BB hot water. The flame of the candle burning in the flask C in the developing hydrogen atmosphere went out when the water rising into the flask reached the point D. (§19).

Fig. 2: In this experiment Scheele placed the flask B tightly over the candle C having fixed "a tough mass" on the bottom of the dish. Then he filled the dish with water "after the flame was extinguished and everything had become cold." (§21).

Fig. 3: Scheele prepared oxygen by distillation of nitre in a glass retort and employed a bladder, moistened and emptied of air in place of a receiver. (§35).

Fig. 4: Scheele explained the drawing as follows: "I place in a soft bladder (AA) the material from which I intend to collect the air, e. g.; chalk; above this chalk I draw the bladder together with twine (B); I then pour above it the acid diluted with water and press out the air as completely as possible. I finally tie up the bladder above at C. I then untie the twine B and the acid runs upon the chalk; it immediately drives out the aerial acid (carbondioxide,) whereupon the bladder must expand." (§30,d.).

Fig. 5: The bottle had a hole A in its bottom covered with a small piece of unslaked lime. A tube B went through the cork. The glass C, containing a large bee was tightly fixed upon the bottle. The dish D was filled with sufficient water to have the bottle half immersed in it. After the lapse of seven days the water had risen to E, and the bee was dead. (§85).



Original Drawings of C. W. Scheele concerning his Apparatus

1, 2, 3. Contrivances for collection of carbondioxide.

4. Dipping of wet paper into a bottle filled with hydrochloric acid.

5. Contrivance for the treatment of manganese dioxide with sulfuric acid.

6. Blowpipe flame.

7. Apparatus for the treatment of iron filings with water.

8, 9, 10. Apparatus for the investigation of the composition of air.

11. Contrivance for experiments employing electrical sparks.

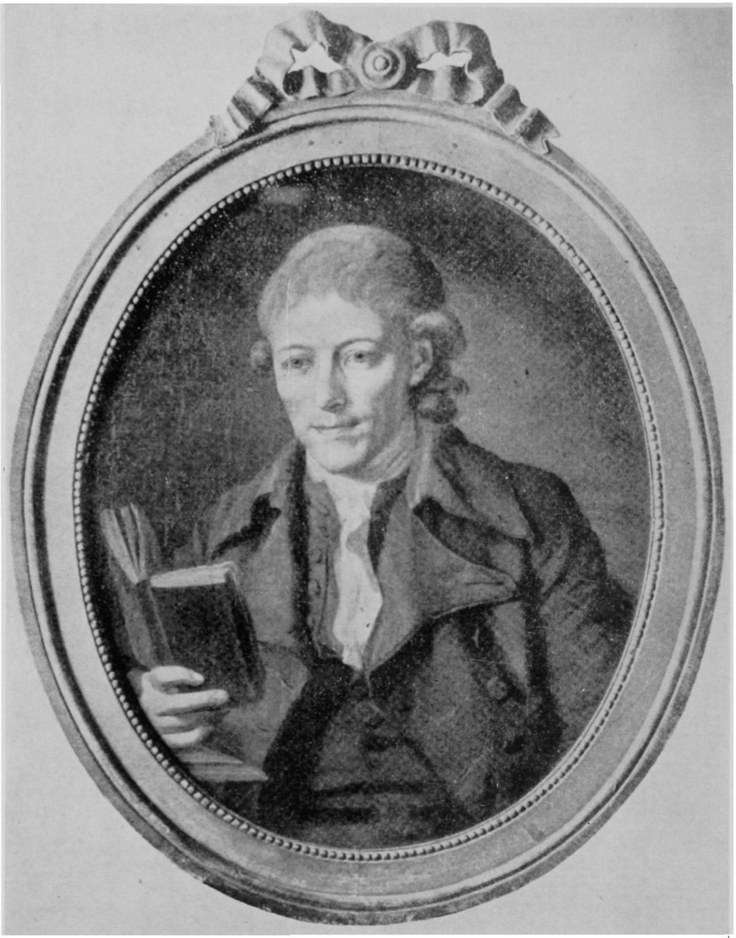
12. Bottle for the preservation of sour fruit juices.

13. Contrivance for the investigation of the phenomena accompanying the solution of corrosive alkalis.

14. Scheele's electrical machine with cushion.

A. J. Retzius (1742-1821) started his career as a pharmacist and passed his examination as a Swedish apothecary in 1761. He devoted himself exclusively to scientific work and became Professor of Chemistry and Natural Science and Director of the Botanical Garden at the University of Lund.

The influence of Retzius on Scheele's work and development cannot be overestimated. He was the first real scientist who recognized the genius in the young apothecary clerk. It was he who caused Scheele to work more systematically and to keep a diary.



Johann Gottlieb Gahn 1745 - 1818

Gahn gained fame by his mineralogical work and is considered one of the founders of mineralogical chemistry. He is remembered in the history of chemistry not only for his isolation of metallic manganese but also for the fact that he was the teacher of Jöns Jacob Berzelius, the creator of our chemical symbols in their present form.

It was Gahn who brought about the personal contact between Scheele and the then foremost Swedish representative of scientific chemistry, Torbern Bergman, which was destined to lead to a collaboration and to results not frequently attained in the history of chemistry.

T. Bergman (1735-1784) was one of the most important chemists of his time, excelling simultaneously in botany, zoology, physics and mathematics. He investigated the influence of temperature on chemical composition and decomposition, postulated the chemical theory of simple and double affinity, suggested the classification of the materia chemica into inorganic and organic. The enormous difference between the elegant and eloquent Bergman and the not very articulate Scheele created initial misunderstandings. Bergman refused the recognition of Scheele's first papers mainly because of their clumsy style.

Carl von Linne' 1707 - 1778

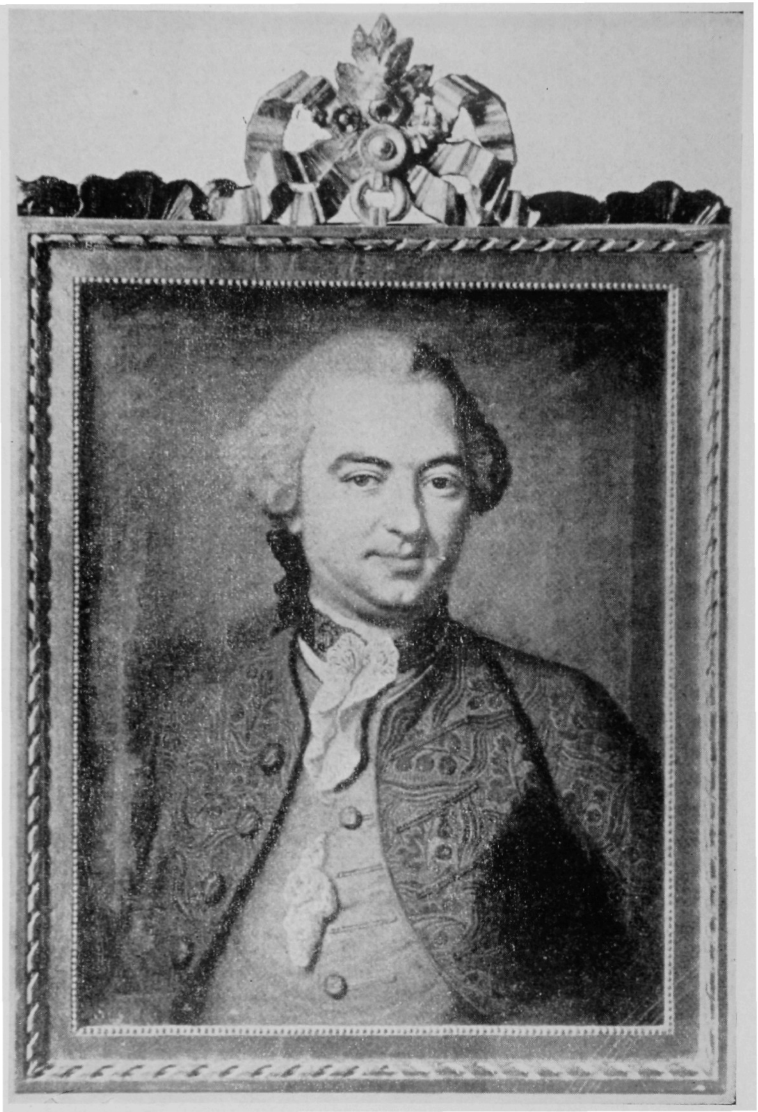
The great botanist and organizer of natural science whose work his contemporaries characterized by the sentence, "God created the world, Linné ordered it," appreciated the work of Scheele very much. He belonged to the group of Swedish scientists who tried to find a place and an income for Scheele when the hopes of the great pharmacist to find a haven in Köping received a setback.

Abraham Baeck 1713 - 1795

The "Archiater" (presiding physician in ordinary to the King) Abraham Baeck was a person of high scientific and social standing. He was an intimate friend of the great Linné and became an ardent admirer of Scheele's.

Baeck presided over the examination board which made the apothecary examination of Scheele an act of reverence to the candidate. In 1782 he invited Scheele to deliver lectures at Stockholm. Scheele refused. "All my experiments," he wrote, "have only one purpose; to make as clear as possible what to me seems difficult and obscure. These experiments would proceed badly if I would be hindered in their continuation by lectures and the presentation of experience already known although new. I am content with my bread although it is modest."

Nine days before his death Scheele wrote Baeck in detail about his illness: "I think," he wrote, "that my death is sure, if the Archiater does not find a way out."



Peter Jonas Bergius 1730 - 1790

It was Bergius, Professor of Natural History and Pharmacy at the School of Medicine at Stockholm, who, in 1774, suggested the election of the "studiosus pharmaciae" Carl Wilhelm Scheele as a member of the Swedish Royal Academy of Science, and it was he who, in 1777, submitted to Scheele the offer of the Prussian King Frederick the Great "to go as a chemist to Berlin and to stay there." Although an annual salary of 1000 ducats was offered, Scheele refused to leave Sweden and pharmacy.

Per Wilhelm Wargentin 1717 - 1783

P. W. Wargentin was Secretary of the Swedish Academy of Science when Scheele became a member and he remained in this position until his death in 1783.

His connection with Scheele was restricted mainly to the mailing of the financial support granted Scheele by the Academy (from 1777-1780 annually 100 "Reichsthaler", equal to about $71.00; from 1781-1784, 60 R. Th., and then again 100 R. Th.). Wargentin acted as a registrar without taking much personal interest. In 1779 he stated in a letter to Scheele with the satisfaction of a trustee who sees that the money he spends is not wasted: "I very often see in foreign journals your experiments reported and praised."

J. C. Wilcke [1732-1796] was a prominent physicist, since 1784 Secretary of the Swedish Academy of Science, and ardent admirer of Scheele's. After the death of Bergman, Wilcke wrote: "Since we lost Bergman, it is you in whom we put the greatest confidence that you will keep up our [Sweden's and the Academy's] reputation as to chemistry."

In a letter of October 7, 1784 Wilcke wrote: "I am still of the opinion that Priestley learned by his correspondence with Bergman of your theory on fireair before he started his experiments. If you know otherwise, please correct me."

Carl Wilh. Scheele
Apothekare i Köping.

Scheele's Signature in 1786

In spite of all the honors bestowed upon Scheele, he remained always and above all an "Apothekare", the title by which he designated himself whenever he signed a document.

Scheele took his duties as a pharmacist very seriously. Although there was no greater and perhaps no other pleasure for him than to "clear up new phenomena" (letter written to J. G. Gahn on December 26, 1774), his research had to wait until his pharmaceutical work was taken care of. In a letter to J. C. Wilcke (March 18, 1784) Scheele wrote: "I am doing my chemical research only as a sideline in order not to neglect my duty in my apothecary shop."

Silver Shield on Scheele's Coffin

The inscription reads in English translation as follows:
Carl Wilhelm Scheele, apothecary at Köping, member of the Royal Academies at Stockholm, Berlin, Turin, etc. Born at Stralsund on December 9,* 1742, married on May 18, 1786, and deceased on May 21st of the same year.

> "Yea, saith the Spirit, that they may rest from their labors;
> and their works do follow them." Rev. Ch. XIV, V. 13.

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* L. v. Crell and recently Zekert are of the opinion that C. W. Scheele's birthday was the 19th and not the 9th of December. According to Riesenfeld this difference may find an explanation in the fact that at the time of Scheele's birth in Pomerania the Julian and not the Gregorian calendar still was in force, meaning a difference of about ten days.

Carl Wilhelm Scheele at the Age of about 25 Years

This picture represents the only really authentic portrait of Scheele that came down to the present time.

Portrait of C. W. Scheele

Painted by J. Falander

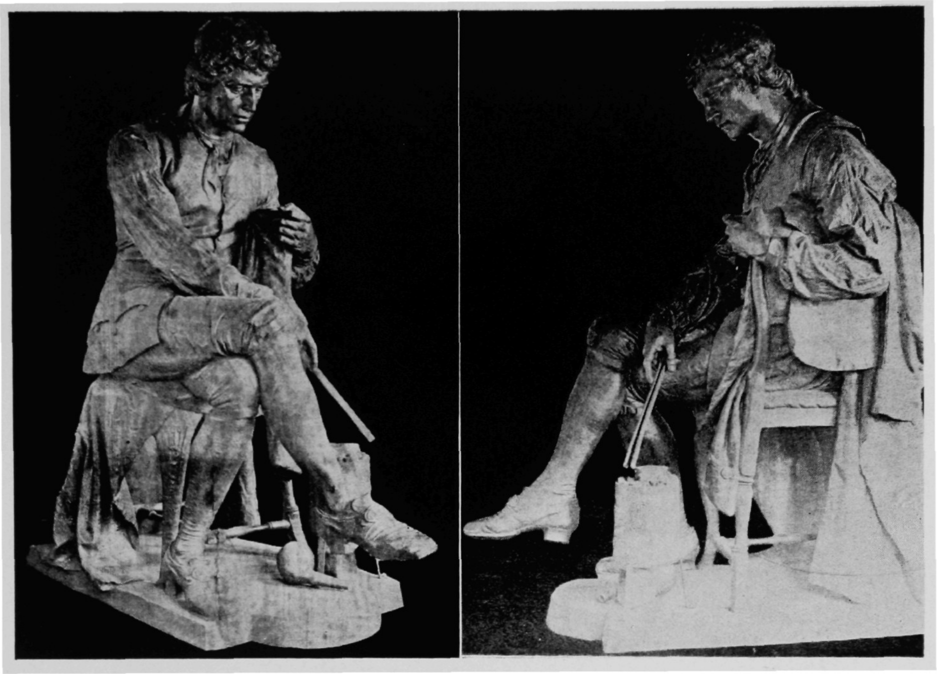
This portrait is the best known and most published of the pictures pretending to be likenesses of the great pharmacist. It was, however, like the others, with the only exception of the one showing Scheele at about 25, prepared after his death. It represents, therefore, more the idea the painter had of Scheele's appearance than a real likeness.

Portrait of C. W. Scheele

This portrait is reproduced from an engraving the engraver of which is unknown. It is assumed that the relief portrait on the medal issued by the Swedish Academy of Science in 1790 served as the model for the artist.

Tablet and a Sculpture representing The Head of Carl W. Scheele

Attached to the house where Scheele was born, in 1874.



Scheele Monument at Stockholm

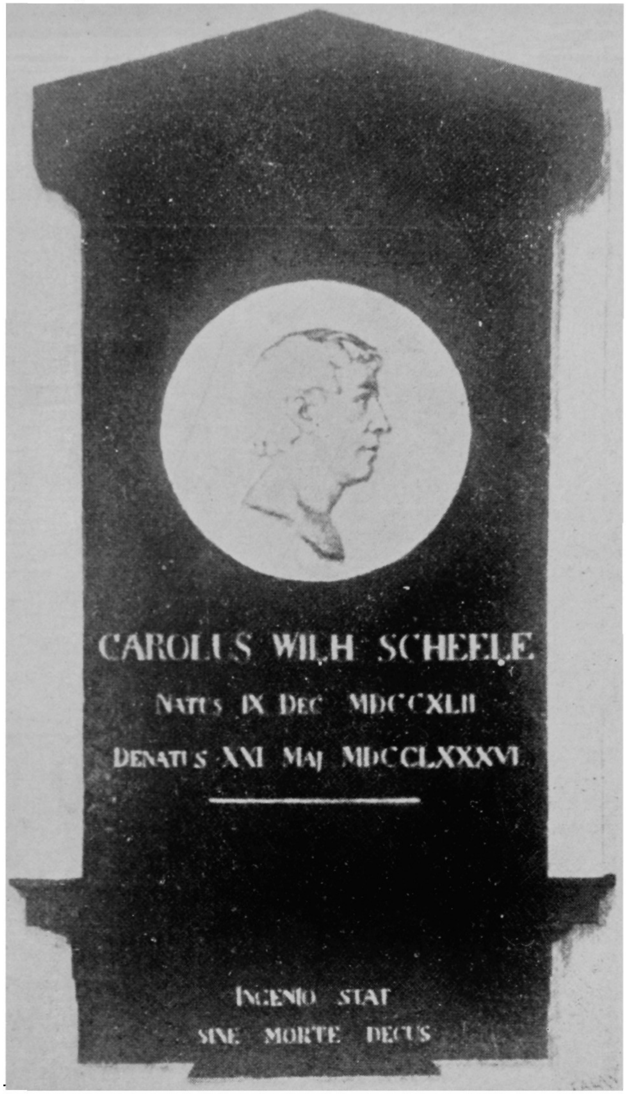
Prepared by the Sculptor
J. Boergeson.

Unveiled on the Occasion of the
150th Anniversary of Scheele's
Birth in 1892
By
The King of Sweden

Scheele Monument at Köping

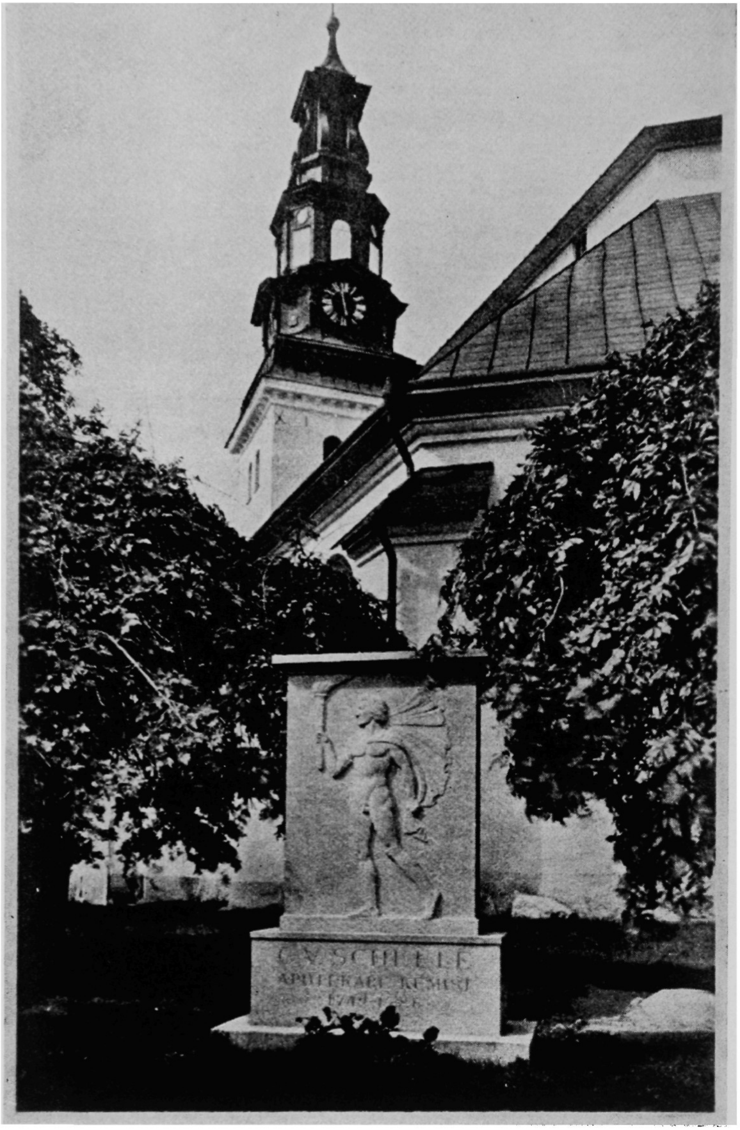
This bronze statue was prepared by Milles and unveiled on June 18, 1912.

The idea was to present at this place of Scheele's professional activity not an idealized picture of a hero of science, but the apothecary in the modest attire and attitude which very likely were significant of him.



Epitaph of Carl W. Scheele

This epitaph adorns one of the walls in the church at Köping. Prepared by J. Falander, it was dedicated by the "Apotekare Societeten", i. e. association of apothecaries, at Stockholm, in 1827.



Monument on Scheele's Grave

This monument is the work of the sculptor Olof Ahlberg. It was erected on Scheele's grave at Köping in 1928.

A genius carrying the torch, there cannot be any better symbol for a man, who while under the pressure of most urgent material need, wrote: "you certainly would think that having to devise means to fill his stomach, he will leave experimental chemistry. O no! This noble science is my eye*) (letter to J. G. Gahn, written on Oct. 10, 1775).

*) This somewhat peculiar expression certainly means that the science of experimental chemistry was to Scheele all that he could see.

Medals coined in Honor of C. W. Scheele

There have been coined several medals in honor of Scheele. Of those shown here the one to the left was issued in 1789 by the Swedish Royal Academy of Science. The relief portrait is considered to be one of the best likenesses of Scheele. The Latin inscription on the reverse means in liberal translation: "The Fame of the Genius Is Immortal."

The medal to the right below the intermedium was issued by the same Academy in 1827. The reverse shows the veiled statue of Isis with Hermes attempting to lift the veil. The Latin inscription referring, naturally, to Scheele says: "He Has Revealed the Secrets of Nature."

The medal to the right above the intermedium was issued on the occasion of the International Meeting of Physiologists at Stockholm in 1926.

It is significant that all these medals mention only the "Chemicus" not the "Apothecarius" Scheele. There exists, however, a fourth medal coined in 1892 on the occasion of the 150th anniversary of Scheele's birthday. This medal shows on its obverse the monument of Scheele erected in the same year at Stockholm and the Latin inscription: "Carolo Guilmo Scheele, Pharmaceutae Chemico Grati Cultores Ordo Pharmaceut. Svercia.", i.e. "In Memory of the Pharmacist and Chemist C. W. Scheele and in Grateful Reverence the Swedish Association of Apothecaries." The reverse shows Scheele's pharmacy at Köping and the inscription: "Domestici Parietes Ipsum Non Famam Continuerunt", i.e. "The Domestic Walls Enclose the Body Not the Fame."

Stamps Issued in Honor of C. W. Scheele

Design of two stamps issued by Sweden on the occasion of the bicentenary of the birth of Carl Wilhelm Scheele. The difference between the two stamps is one of color and value, the one reproduced above being green and a 5 öre stamp (equal to about one cent) while the other is a claret 60 öre stamp (equal to about 15 cents). The portrait on the stamp is a somewhat retouched copy of the only authentical picture of Scheele that came down to us and has been reproduced on page 47 of this brochure.

Timetable of C. W. Scheele's Experiments

As Reported by Himself in His Letters and Notes[1]

Acetic acid: Product of distillation of lignum guajaci (December 26, 1774); reaction of potassium acetate with carbonic acid (March 29, 1776); formation of acetic acid in old lard (October 4, 1776).

Acids: Water fixes more or less all *"acida pura"*, i. e. acid anhydrides (March 1, 1773).

Air: One third of the air brought together with ammoniacal cuprous oxide is absorbed by the latter (before spring 1770); properties of air in which animals have breathed (before fall 1770); air is absorbed by linseedoil (before fall 1770); air if shaken with fresh blood, looses its capacity to maintain combustion (1771-1772); the statement of Priestley concerning the regeneration of air unfit for breathing by plants is wrong (May 1772); apparatus for the demonstration of the composition of air (November 1775); atmospheric air consists of two constituents, vitiated air (Scheele's term for nitrogen) and fireair. The air contained in water is mostly fireair (November 1775); the statement of Priestley concerning the improvement of vitiated air by shaking it with water is wrong (November 1775); examination of air at different seasons (November 27, 1780); unsuccessful attempts to prepare atmospheric air by shaking hydrogen, nitrogen and oxide of nitrogen with water (April 7, 1780).

Albumen: Conformity between casein in milk, albumen in eggs and some substance contained in human bloodserum (June 9, 1781).

Alkali: Distillation of caustic alkali with coals (spring 1770); lime cannot be precipitated by alkali carbonate (spring 1770); nature of alkali bisulfate (December 1771); decomposition of alkali sulfate by hydrochloric acid (December 1771); formation of saltpetre by treatment of alkali sulfate with nitric acid (December 1771); both fixed alkali *(alkalia fixa)* can be evaporated by fire (1771-1772); the fact that melted caustic alkali forms a solution which coalesces, is due to the corrosion of the earthen crucible (1771-1772); the statement that alkali can be transformed into alumina by repeated melting is wrong and based on the corrosion of the earthen crucible (November 16, 1772); melting of fixed alkali with sand drives out carbon dioxide, melting of sulfurated potash with sand drives out sulfur (January 1773); combination of absorbent earths with alkali (March 1, 1773); attempt to prepare a perfectly pure alkali (December 26, 1774).

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[1] This table, arranged according to the substances to which the experiments were mainly devoted, represents an extract from the *"Register"* (Index) in A. E. Nordenskiöld's book "Carl Wilhelm Scheele, *Nachgelassene Briefe und Aufzeichnungen,*" Stockholm, 1892, translated from the German original into English by the editor. According to Nordenskiöld his list does not include references to Scheele's printed essays or treatises. "Since, however," Nordenskiöld concludes, "most of the experiments mentioned in Scheele's publications are at least touched in his letters and laboratory notes, I hope that this arrangement will furnish a clear and not too incomplete contribution to the knowledge of Scheele as a researcher in chemistry."

Alumina: Reactions of alum, and potassium content of alum (before 1768); crystals of ammonium alum (before 1768); reactions of alumina (before 1768); a solution of alum if treated with some iron precipitate yields a precipitate of alumina (before 1768); supposed solubility of alumina in water (before 1768); precipitation of alumina by ammonia as well as by potassium carbonate (1770); basic aluminum sulfate is insoluble in water (1771-1772); compound consisting of alumina, hydrate of lime and gypsum, (1774); reactions of a solution of alum with lime-water, with gypsum, with chalk, and with tartar (January 3, 1775); basic sulfate of alumen (September 10, 1779); the precipitation of alumina out of its solution by iron or zinc is due to the formation of a basic salt (October 4, 1779); the formation of a white precipitate if alumina is added to limewater, representing a combination of alumina and lime, is probably due to the presence of some sulfuric acid (January 2, 1784).

Ammonia: Reaction of ammonium carbonate with caustic alkali, tincture of antimony and sulfurated potash (before 1768); ammonia gas is gained from spiritus cornu cervi (a spirituous solution of crude ammonium carbonate, the latter being obtained by the distillation of hartshorn). The inflammibility of ammonia gas is stated (spring 1770); assumption that ammonia originates from fixed alkali plus phlogiston (spring 1770); ammonia is completely decomposed by nitric acid as well as by black manganese (1771-1772); ammonium carbonate is decomposed by burning coals (1771-1772); ammonia is a common vitiation of the air, especially in sleeping rooms (January 27, 1777); ammonia produces nitrogen if brought together with nitric acid and manganese dioxide (February 1, 1783).

Antimony: Reactions of antimony with hydrogen sulfide (before 1768); reaction of antimony with tartar, i. e. potassium bitartrate (before 1768); antimony is soluble in a solution of sulfurated potash and precipitates again after addition of acids (before 1768); reactions of diaphoretic antimony, i. e. potassium antimonate (March 28, 1768); distillation of antimony with salt, with corrosive sublimate, with lead chloride, with silver chloride (May 24, 1776); traces of butter of antimony, i. e. antimony trichloride, can be obtained by distillation of the metal with salt in an earthen crucible (August 30, 1776); preparation of powder of algaroth, i. e. antimony oxychloride (February 7, 1778); preparation of potassio-tartrate of antimony (February 7, 1778); preparation of diaphoretic antimony (December 1, 1767).

Ants: The calcinated residue remaining after the distillation of ants contains lime, calcium phosphate and some alkali (December 26, 1774); how to catch ants (December 26, 1774).

Arsenic: A solution of arsenic trioxide, if treated with hydrogen sulfide, yields a yellow precipitate (before 1768); arsenic acid is obtained by treatment of arsenic trioxide with nitromuriatic acid (1771-1772); effect of chlorine on arsenic acid (March 28, 1773); reactions of arsenic acid (March 28, 1773); the experiments with arsenic acid have come to a conclusion (March 6, 1775); arsenetted hydrogen (December 22, 1775).

Baryta: "The special earth in black manganese". It is present also in plantash (1771-1772)[2]; the spatlike crystals on black manganese contain the new earth combined with sulfuric acid (February 28, 1774); "the new earth in *magnesia nigra mechanice mixta*" (1774); Scheele sends Gahn black manganese with crystals consisting of the new earth combined with sulfuric acid (March 28, 1774); Gahn discovered the presence of the same "new earth" (baryta) in heavy spar. Examination of this mineral by Scheele (May 16, 1774); improvement of Gahn's method of isolation of baryta from heavy spar (June 27, 1774); decomposition of heavy spar by treating the powdered and levigated mineral with potassium carbonate and coaldust for about half an hour "keeping the mixture in a tender flow", and, after having separated the residue from the liquid, dissolving the residue in nitric acid (June 27, 1774); potassium ferro cyanide "saturated with nitric acid", precipitates lead but not a solution of heavy spar (June 27, 1774); preparation of barium hydrate (summer 1774); detailed report on the reactions of baryta (March 9, 1776); distillation of formic and nitric barium (summer 1774); refutation of the statement of Gahn that the "earth" contained in heavy spar can be precipitated by potassium ferro cyanide (summer 1774); statement of the rather slight solubility of barium nitrate (January 12, 1776); heated barium nitrate yields barium hydrate (March 9, 1776)[3]; statement that baryta is indispensable in chemistry (March 29, 1776); potassium barium tartrate (March 29, 1776); heavy spar contains some lime (May 10, 1777); barium carbonate is slightly soluble in water (March 22, 1782); remarkable reactions of baryta with ammonium ferro cyanide (April 5, 1782).

Benzoic acid: Reactions of benzoic acid (before 1768).

Bloodwater: There are fargoing analogies between human bloodwater and albumen (June 9, 1781).

Boric acid: Profound investigation of borax and "sedative salt" (before 1768); borax consists of mineral alkali and "sedative salt" (March 28, 1768); "sedative salt" is no salt but a special acid; reactions of this acid (April 22, 1768)[4]; borax contains sodium and boric acid (1768); reactions of borax with lime (spring 1770); "sedative salt" cannot be prepared of lard, alumina and water according to Baumé's formula (May 24, 1776).

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[2] "Here we have another proof for the fact that Scheele's investigation of black manganese (leading to the discovery of manganese, baryta, chlorine, etc.) was executed during the years 1771/72." (Nordenskiöld, Scheele, p. 457).

[3] "This report contains much that at his time was absolutely new to science and fell afterwards again into oblivion. Thus the important method of preparing caustic barium by heating barium nitrate had to be reinvented by Fourcroy and Vauquelin in 1797, before it was given a place in the annals of chemistry." (Nordenskiöld, Scheele, p. 250).

[4] Nordenskiöld (Scheele, p. 30) considers the statements made here by Scheele as the "first determination of the nature of boric acid," and continues as follows: "The fact that borax consists of sodium and 'sedative salt' had been proved already by Baron in the Memoirs of the Parisian Academy in 1747 and 1748. However, as to the nature of the 'sedative salt,' he had still very unclear concepts. Scheele's contemporaries had very different opinions on this question, the one more senseless and unchemical than the other."

Camphor: Reactions of camphor (before 1768); camphor if distilled with alumina yields an oil which remains liquid in the cold (March 9, 1781).

Carbondioxide: Carbondioxide is absorbed by water. Apparatus to collect the gas in water (spring 1770); reaction of carbondioxide with lacmus (spring 1770); carbonized water and its reactions (spring 1770); carbondioxide is developed by treatment of organic substances with manganese dioxide and sulfuric acid (1771-1772); method of saturating water with carbondioxide (March 1, 1773); the statement that carbondioxide if absorbed by olive oil can be transformed into an inflammable gas by boiling the oil, is wrong (January 27, 1780); pure iron if detonated with saltpetre does not yield carbondioxide. It is a content of plumbago in the iron where carbondioxide originates from during the process mentioned (January 30 and March 13, 1780); the effect of carbonated water on iron (March 13, 1780); carbondioxide seems to have some affinity to air (October 20, 1780).

Casein: Casein corresponds with albumen (June 9, 1781).

Cerite: Examination of cerite from Batnäs (January 18, 1782); examination of cerite sent to Scheele by Hising (May 31, 1782).

Chlorine: Hydrochloric acid is eagerly absorbed by water (spring 1770); a bottle filled with hydrochloric acid gas develops fumes with hydrogen. Apparatus for the demonstration of this phenomenon (spring 1770)[5]; dephlogisticated hydrochloric acid dissolves cinnabar (1771-1772); dephlogisticated hydrochloric acid is obtained by treating black manganese with hydrochloric acid. Reactions and qualities of dephlogisticated hydrochloric acid (March 28, 1773); completely dephlogisticated hydrochloric acid does not precipitate silver out of its solutions (June 27, 1774); dephlogisticated hydrochloric acid (December 22, 1775); reactions of hydrochloric acid with saltpeter (January 12, 1776).

Clay: White clay contains iron but no sulfuric acid and is insoluble in water (January 1773).

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[5] Nordenskiöld (Scheele, p. 49) accompanies the "P.M. *(Pro Memoria)* heard from Scheele" which J. G. Gahn wrote down in spring 1770, with comprehensive annotations concluding as follows: "We see that Scheele was an excellent gas chemist for his time as early as in summer 1770, that ammonia and hydrochloric acid gas were known to him long before they were described by Priestley, that he knew already then about the capacity of the metals to combine with different amounts of oxygen . . . to quite different metallic calxes and by the combination of these calxes with acids to yield quite different salts and precipitates,—a knowledge so important to the entire theoretical structure of chemistry. These observations of Scheele led him, as later letters prove, to the assumption that alkali and alkaline earths can be reduced like the metallic calxes and that it is possible to transform the metallic calxes into acids by further oxidation or "loss of phlogiston."

Coals: Capacity of coals to absorb gases (March 1, 1773)[6]; vegetable coal contains some iron. The same is the case of coal obtained from potassium bitartrate (summer 1774); origin of carbondioxide (December 22, 1775).

Cobalt: Cobalt is found in blue starch (before fall 1770).

Combustion: Scheele's theory on combustion (November 1775).

Copper: Crystallized double salt originating from copper nitrate and ammonium chloride and the reactions of this new compound (before 1768); an ammoniacal solution of copper sulfate is not precipitated by zinc (before 1768); potassium carbonate turns blue in the presence of copper (before 1768); reactions of salts of different stages of oxidation, i.e., various oxides and oxidulates of copper, with ammonia (before 1768 and in 1770); distillation of copper acetate (1771-1772); crystals obtained from the combining of coppernitrate with ammonium chloride (February 28, 1774); oxide and oxidul compounds of copper (March 10, 1775); examination of the blue color reactions of copper oxide with ammonia (March 10, 1775); precipitation of copper with iron (summer 1775); examination of two green dyestuffs (May 24, 1776); basic copper chloride (May 24, 1776); copper oxide is soluble in carbonated liquids (October 4, 1776); formation of copper sulfate by roasting copper and sulfur (February 9, 1777); removal of iron from copper sulfate (February 9, 1777); Scheele's Green (February 9, 1777); constituents of verdigris and causes for the formation of verdigris (February 9, 1777); preparation of Scheele's Green (February 11, 1778).

Crystals: Small crystals show the crystal forms of the salts most distinctly (September 6, 1774).

Cyan: Substances giving blue colored liquids if melted with alkali carbonates (before 1768); sodium carbonate if calcinated with blood yields a substance which turns blue the color of solutions containing iron (before 1768); extract from Berlin (Prussian) Blue with ammonia as well as with alkali (before 1768); impure potassium and sodium carbonate contain small amounts of potassium ferro cyanide (before 1768); preparation of crystallized potassium ferro cyanide (before 1768); the blue color reaction takes place only after addition of acid (February 5, 1768); the blue substance precipitates only with metals, not with alkali or earths (February 5, 1768); Berlin (Prussian) Blue treated with sodium carbonate yields ferric oxide if melted with saltpetre (February 5, 1768); Berlin (Prussian) Blue is ironcalx combined with a special inflammable substance (February 5, 1768); ashes and sodium carbonate treated with sulfuric acid and ferro sulfate yield a blue dyestuff (February 5, 1768); addition of acid to potassium ferro cyanide (lye) is necessary in order to obtain a blue color with iron (April 22, 1768); the coloring salt is destroyed if

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[6] Nordenskiöld (Scheele, p. 113) writes: "This peculiar discovery is mentioned also in Scheele's treatise on air and fire. However, the credit is mostly given to Felice Fontane who demonstrated the phenomenon in 1777. Scheele's priority is definitely proved by his letter of March 1, 1773."

slightly heated, but regenerated if melted (April 22, 1768); Berlin (Prussian) Blue contains a kind of acid but no hydrochloric acid (April 22, 1768); crystallized potassium ferro cyanide (April 22, 1768); extract from Berlin (Prussian) Blue with ammonia; boiling of Berlin (Prussian) Blue with lime (spring 1770); potassium ferro cyanide if distilled yields a gas which smells like ammonia (spring 1770); the largest amount of the dyeing substance in Berlin (Prussian) Blue is obtained if the calcination takes place in a well closed vessel and the mass is subjected to quick cooling (spring 1770); natural Berlin (Prussian) Blue and the artificial one are not identical (November 16, 1772); experiments with Berlin (Prussian) Blue (summer 1774); potassium ferro cyanide (lye) loses its coloring influence if strongly digested with sulfuric acid (summer 1774); crystallized potassium ferro cyanide (summer 1774); digestion of Berlin (Prussian) Blue with lime as well as with potassium carbonate (June 27, 1774); preparation of potassium ferro cyanide (lye) and the reactions of this substance (September 10, 1779); the coloring substance in Berlin (Prussian) Blue seems to be an acid (December 22, 1780); Scheele believes to have definitely determined the coloring substance in Berlin (Prussian) Blue (May 31, 1782); Scheele sends his essay on the coloring substance in Berlin (Prussian) Blue to Bergman (February 28, 1783); which name shall the new substance be given? (March 28, 1783); hydrocyanic acid is the weakest of all acids. Method of purifying hydrocyanic acid from hydrogen sulfide (March 28, 1783).

Decay: Alkali carbonates crystallize with gases generating from decaying substances (before 1768).

Dyeing: Dyeing of textile fiber cannot be based on the chemical principles of precipitation.

Electricity: Unsuccessful electrolytic experiment (January 12, 1776); Scheele's electrical machine (March 26, 1777); chemical effect of the electrical spark on oxygen (May 28, 1779).

Ether: Separation of ether from alcohol (spring 1770); observation of the change ether is undergoing if preserved for a longer period of time (spring 1770); determination of the amount of ether to be gained from a certain amount of alcohol (February 7, 1777); unsuccessful attempts at the preparation of acetic ether (September 28, October 3, November 2, 1781).

Flame of a candle: In the middle of a candle flame lead oxide is reduced but coal is not burned (before 1768).

Flame reaction: By sodium nitrate, potassium nitrate, boric acid (December 11, 1767); by lead, lead oxide, ammonia, sodium chloride, copper, mercury, antimony, and Berlin (Prussian) Blue (before 1768).

Fluorine: Fluorite is soluble in diluted hydrochloric or nitric acid (March 9, 1776); crystals originated from hydrofluoric acid (May 10, 1776); unsuccessful attempts at preparing hydrofluoric acid free from silica (May 10, 1776); potassium fluosilicate (May 10, 1776).

Gallic acid: Tincture of nutgall and its composition. Reactions of gallic acid (spring 1770); gallic acid is similar to benzoic acid (spring 1770).

Garnet: Composition of garnet (January 1773).

Globuli martiales: New process for the preparation of globuli martiales, i.e. tartarus ferratus in form of globuli (before December 1767).

Glycerin: Conclusion of the experiments concerning "the sweet in fatty oils" (September 11, 1783).

Gold: Various reactions of gold (1771-1772); neither nitrogen nor hydrogen precipitate gold out of its solutions (1771-1772); detonation of fulminating gold (March 10, 1780).

Graphite: Chemical examination of graphite (November 20, 1778); residue after the roasting of plumbago. The iron content is probably a common one. The evaported substance is neither sulfur nor molybdic acid (December 28, 1778); the investigation of graphite has been brought to an end (June 7, 1779); composition and reactions of graphite (July 23 and September 13, 1779).

Gypsum: By treating sulfuric acid with alcohol Scheele obtained a precipitate consisting of gypsum (December 22, 1775).

Hartshorn: Reactions of burnt hartshorn (spring 1770); reactions of hartshorn if distilled and calcinated (October 23, 1778).

Heat: Constituent of many substances (November 1775); a glass mirror reflects the heat rays of the sun but not of a stove fire (November 1775); polished metal reflects heat rays of a stove fire without becoming warm itself (November 1775); effect of radiating heat on air (November 1775); the heat rays of the sun penetrate glass, the heat rays of a stove fire do not (November 1775); reflections about exothermic processes (November 27, 1778); reflections on animal warmth (March 10, 1780).

Hydrochloric acid: Properties of the acid obtained as product of the distillation of sodium chloride with the residue from the preparation of ether (spring 1770); hydrochloric acid in its most concentrated form is a gas; the decoloration of yellow hydrochloric acid containing iron by means of tin is due to the reduction of iron (March 29, 1776).

Hydrogen: Preparation of hydrogen by action of water on iron; apparatus demonstrating this action (1767); a mixture of hydrogen with steam is not inflammable (1767); hydrogen does not contain carbondioxide (1767); hydrogen is generated by boiling iron with a solution of tartar (1767); hydrogen is not absorbed by water and is lighter than air (spring 1770); tincture of litmus is not changed by hydrogen (1771-1772); hydrogen is not preexistent in the metals (January 30, 1780); combustible air is formed besides carbondioxide on the occasion of the distillation of essential oils (March 13, 1780) and is also obtained by digestion of metals with alkali (April 7, 1780); no odorless hydrogen has been observed (April 5, 1782).

Hydrogen sulfide: Liquid and solid hydrogen sulfide (before 1768) reactions of hydrogen sulfide with metals (before 1768); some reactions of hydrogen sulfide (March 28, 1768); the gas generating from iron filings treated with sulfuric acid blackens leadcalx (1770); reactions of hydrogen sulfide (1770); hydrogen sulfide can be separated from alkali sulfide completely by means of lead oxide; effect of hydrogen oxide on air (1771-72).

Iron: Iron if treated with water produces hydrogen. Apparatus for the demonstration of this phenomenon (before December 1767); Iron yields hydrogen with all acids except nitric acid (before December 1767)[7]); solution of ferro sulfate in aqua regia, i.e. nitromuriatic acid, and the peculiar reactions observed hereby (before 1768); red crystals obtained from aqua regia containing iron, after ammonium chloride had been dissolved in the liquid under employment of heat (before 1768); presence of iron in all vegetables and also in sodium carbonate (February 5, 1768); an extract from Berlin Blue with spirit of ammonia represents an excellent reagent on iron (April 15, 1768); white crystallized compound consisting of ironoxide and sulfuric acid (spring 1770)[8]); Iron is soluble in carbonated water (spring 1770); solution of ironoxide in sulfuric acid (1771/72); behaviour of iron if melted with borax and saltpetre (1771/72); iron is present in alumina, in green and in white glass (1771/72); ferro sulfate is oxidized by a goldsolution (1771/72); iron if dissolved in nitric acid yields dephlogisticated nitric acid not carbondioxide (1771/72); there may be substances which are attracted by magnets without containing iron (summer 1774); distillation of ironoxide with ammonium chloride, and of iron with ammonium chloride (May 10, 1776); reduction of iron chloride by means of zinc, tin or iron (May 10, 1776); reason for the precipitation of iron from the mineral water of Pyrmont (August 30, 1776); detection of manganese in a sample of iron sent to Scheele (February 9, 1777); an easily crystallizing double salt of iron and ammonia (May 10, 1777); residue after solution of pig iron in acids (July 23, 1779); the residue after the solution of iron in sulfuric acid consists of graphite (September 13, 1779); reduction of ironoxide (October 4, 1779); the effect of water on iron with and without exposition to air (January 30, 1780); capacity of water to dissolve iron (May 8, 1780); white crystals similar to alum and consisting of ironoxide and sulfuric acid (May 8, 1780); red-short iron contains sulfur (May 8, 1780); effect of dry and moist air on iron filings (November

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[7]) **Nordenskiöld (Scheele, p. 54) accompanies the publication of this report of Scheele with the statement that the theoretically important observations concerning the development of hydrogen by treatment of iron not only with inorganic acids but also with organic ones and by rusting of iron in water were completely new at this time. Cavendish said in his paper concerning "experiments on factitious air" (1766) expressly: "I know of only three metallic substances, namely, zinc, iron and tin, that generate inflammable air by solutions in acids; and those only by solution in the diluted vitriolic acid or spirit of salt."**

[8]) **This salt, says Nordenskiöld (Scheele, p. 49), "has been rediscovered by Buchholz, Rink and Thenard almost half a century later. The report of Scheele concerning the solution of iron in acids shows that the different degrees of oxidation of iron were known to him before 1770."**

13, 1780); Meyer's white earth obtained from bog ore (June 1781); water if standing over iron filings develops hydrogen (July 13, 1781); reason for the precipitation of ocher out of a solution of ferro sulfate (July 13, 1781); iron is an essential ingredient of blood lye (March 22, 1782); attempts at separation of iron and alumina by means of sulfurated potash (February 1, 1783); preparation of crocus martis Stahlii, i.e. a special impure ironoxide the formula for the preparation of which was originally given by G. E. Stahl (December 1, 1767).

Ivory: Chemical examination of ivory (February 28, 1783).

Litmus: Reactions of litmus (spring 1770).

Lead: Reactions of lead glass, i.e. melted litharge forming a transparent mass (before 1768); the effect of heat on minium (before 1768), minium and litharge absorb carbondioxide out of ammonium carbonate (before 1768); reaction of basic lead chloride with caustic and carbonic alkali (before spring 1770); reactions of lead chloride with acetic and basic acetic lead oxide (before spring 1770); composition of lead chloride, basic lead chloride and several other lead compounds (before spring 1770); reactions of lead acetate (spring 1770 and May 24, 1776); black minium, i.e. lead peroxide, treated with turpentine (1771/72); method to detect small amounts of lead in metalalloys (March 28, 1774); theory of the preparation of lead carbonate (August 30, 1776); lead sulfate is soluble in caustic alkali and lime water (October 4, 1776); preparation of lead peroxide (April 5, 1782); brown minium is nothing but "dephlogisticated lead calx" (April 2, 1784).

Lime: Reactions of lime (before 1768); lime is precipitated by oxalic acid (spring 1770); reaction of calcium salts with tartaric acid (spring 1770).

Linseedoil: Reasons for the drying of linseedoil (November 27, 1778).

Magnesia: Reactions of magnesia (before 1768 and 1770); inclination of magnesia to form double salts (February 12, 1775); preparation of magnesia alba on a large scale (January 12, 1776); crystals of ammonium magnesium sulfate (May 10, 1776); reactions based on the inclination of forming double salts (May 10, 1776); examination of "Bohemian air salt" which proved to be magnesium sulfate (October 23, 1778).

Manganese: Reactions of pyrolusite (1771/72); distillation of pyrolusite with sulfur (1771/72); mercury is soluble if digested with pyrolusite and hydrochloric acid (1771/72); digestion of pyrolusite with sulfuric acid (1771/72); effect of the digestion of pyrolusite and gum arabic with hydrochloric acid (1771/72); "black magnesia is a special kind of earth." Examination of its reactions (March 28, 1773); the reason for the turning blue of fixed alkali if calcinated (March 28, 1774); pyrolusite freed from iron (May 16, 1774); experiments concerning the reduction of pyrolusite (May 16, 1774); the solution of pyrolusite in sulfuric acid has sometimes a rose-red color which is apparently due to a further dephlogistication of pyrolusite (May 16, 1774 and April 7, 1780); the statement of Sage that pyrolusite consists of cobalt and zinc is wrong; preparation of pyrolusite freed from iron (May 16, 1774); reactions of manganese regulus, development of hydrogen if treated with sulfuric acid (June 27, 1774); manganese regulus is a new semimetal (June 27, 1774); separation of manganese from iron (February 1775 and March 6, 1775); determination of manganese in iron and steel (January 25, 1777); inclination of manganous oxide to form double salts (January 25, 1777); a certain amount of pyrolusite very finely powdered, may very likely ignite linseedoil and hempoil (April 30, 1784).

Mercury: Changes of color of cinnabar while heated (before 1768); distillation of cinnabar and mercury oxide with oil (before 1768); composition of *mercurius sublimatus dulcis,* i.e. mercurous chloride gained by sublimation of bichloride of mercury with mercury (before 1768); reactions of bichloride of mercury with alkali carbonate and chalk (spring 1770); mercury forms different salts if solved in warm and in cold nitric acid; reactions of these salts (1771/72); the effect of sulfurous acid on mercury (November 21, 1774); preparation of mercuric and mercurous nitrate (December 6, 1774); preparation of *mercurius dulcis,* i.e. mercurous chloride, by the so called wet way (December 6, 1774); red mercury precipitate yields fire air if heated (November 27, 1776); mercurous salts (1776); mercurous chloride is soluble in solutions of mercuric salts (1776); reactions of mercurous and mercuric salts (January and February 1777); decomposition of mercurous salts into mercuric salts and metal (February 9, 1777); inclination of forming double salts (February 28, 1777).

Metal calxes: Metallic earths can be deprived of still more phlogiston, i.e. can be transformed into substances of a higher stage of oxydation. (April 9, 1779).

Metals: It is the oxides of metals and not the metals as such that combine with acids (May 24, 1776); reduction of metals by wet processes (December 20, 1780).

Milk: Milk contains a special acid which is not identical with acetic acid (April 7, 1780); lactose yields saccholactic acid, i.e. mucic acid and, if treated with nitric acid, some saccharic acid, i.e. oxalic acid (July 14, 1780).

Molybdenum: Preparation and reactions of molybdic acid and attempts to reduce the acid (May 15, 1778).

Mother-of-pearl: Chemical examination of mother-of-pearl (February 28, 1783).

Nitric acid: Peculiar reactions of nitric acid if purified from chlorine by means of silversalt (June 27, 1774); preparation of nitric acid free from chlorine (May 28, 1779); nitric acid may consist of nitrogen and "dephlogisticated aer vitriolicus," i.e. oxygen (January 2, 1784).

Nitrogen: Preparation of nitrogen from air by absorption of the oxygen of the air through ammoniacal cuprous oxide (March 10, 1775)[9]); vitiated air, i.e. nitrogen, is lighter than atmospheric air (November 1775).

Nitrogen oxide: Nitrogen oxide represents a colorless gas which becomes warm and red if exposed to air (November 1775); nitrogen oxide is formed by distillation of iron oxide with ammonium chloride (May 10, 1776); nitrogen oxide is formed if saltpetre is deflagrated (February 9, 1780).

Nitrous acid: An acid to be separated from its alkali by vegetable acids (December 1, 1767); the reactions of this acid (before 1768); preparation and reactions of nitrous acid (March 28, 1768); nitrite of potassium is obtained by the action of nitric acid on iron or copper and the absorpion of the gas by alkali (March 28, 1768).

Oil of wine: A mixture of oil of wine and sulfuric acid absorbs air (before 1768).

Oils: Behavior of essential oils if distilled and frozen (spring 1770); observation concerning the distillation of solutions of essential oils in alcohol (December 22, 1780); hempoil mixed with pine-soot ignites (September 28, 1781).

Osmosis: Property of various gases to penetrate animal membranes (before fall 1770); observations as to nitrogen oxide; hydrogen penetrates animal membranes easily (1771/72).

Oxalic acid: Reactions of "acetosellsalt" with lime (before 1768); acetosellsalt consists of potassium and an acid (before 1768); composition and reactions of potassium oxalate. Crystallisation of an acid contained in berberis which apparently is identical with the acid of acetosellsalt (spring 1770); potassium oxalate is changed to carbonate by burning (spring 1770); significant reactions of genuine acetosellsalt (September 8, 1774); isolation of oxalic acid by means of baryta (March 9, 1776); lead oxalate (May 10, 1776); attempt at isolation of oxalic acid from its potassium salt by means of lead carbonate (May 10, 1776); oxalic acid is obtained in small amounts by treating lactose with nitric acid (July 14, 1780); intimation of the identity of oxalic acid and saccharic acid (March 28, 1783).

Oxydation, different stages:[10]) Copper (before spring 1770); solution of iron in acids. Experimental proofs for the fact that hereby the iron is not completely dephlogisticated (spring 1770); the nature of the precipitates of iron with alkali depends on the stage of dephlogistication of the iron in the solution (spring 1770); the change of color by melting boraxglass colored with manganese is due to the coals employed (April 24, 1772); stages of oxidation of mercury (December 6,

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[9]) Nordenskiöld (Scheele, p. 236) makes the following annotation: "This extremely particular experiment has been mentioned by Scheele one year earlier in a letter to Gahn of February 28, 1774 and in an undated essay found among other papers in Gahn's property left."

[10]) Nordenskiöld (Scheele, p. 408), states: "The property of metals to form with different amounts of oxygen (or of metalcalxes with different amounts of phlogiston) compounds with completely different chemical and physical qualities, so extraordinarily important for Lavoisier's theory of oxygen, was stated by Scheele already during his stay in Stockholm and during the first years of his stay in Uppsala. He illustrated this property by numerous experiments the reports of which, however, were not paid attention by the contemporary chemists."

1774); stages of oxidation of copper (March 10, 1775); the effect of copper and iron compounds on each other depends on the degree of phlogistication of the compounds concerned (April 16, 1775); stages of oxidation of mercury (1777).

Oxygen: First report on the isolation of oxygen, then called by Scheele "Aer vitriolicus"[11]) by heating of carbonate of mercury oxide (1771/72); carbonate of silveroxide and red mercury oxide yield aer vitriolicus upon distillation (1771/72); vitriolic air "in which fire burns very vividly" is obtained by heating of magnesium nitrate, saltpetre and mercury carbonate (1771/72); vitriolic air is obtained by distillation of black magnesia with arsenic acid (1771/72); the respiration of insects changes oxygen to carbondioxide (November 1775); preparation of oxygen by treating manganese peroxide with sulfuric acid, by heating goldcalx, platincalx, saltpetre, mercury oxide, and finally by heating silvercarbonate and purifying the gas by passing it through limewater (November 1775); oxygen is heavier than atmospheric air (November 1775); the absorption of oxygen by *hepar sulfuris* or by a mixture of sulfur and iron filings is an exothermic process (November 1775); pure oxygen is not changed to nitrogen by decaying substances (May 28, 1779); the best oxygen may be obtained from saltpetre (February 26, 1781); the statement of English chemists concerning the preparation of oxygen by treating minium with sulfuric acid is correct. (April 5, 1782).

Phosphorus: In various gases phosphorus does not luminesce (before 1768); animal earth, i. e. burnt bones etc., consists of lime and phosphoric acid (spring 1770); first preparation of phosphorus from bones (spring 1770); crystals formed in solutions of burnt hartshorn in hydrochloric acid or in nitric acid (March 28, 1774); composition of microcosmic salt (October 17 and December 6, 1774); preparation of mirocosmic salt with "sal perlatum", i. e. sodium phosphate (January 17, 1775); combustion of phosphorus in fire air (November 1775); distillation of phosphoric acid with coals (November 23, 1777); difficulties in the preparation of phosphorus (September 10, 1779); impurities in phosphoric acid prepared from the ash of bones (January 30, 1780); the best method for preparing phosphorus (November 13, 1780); investigation of *"sal perlatum"* (January 25, 1782).

Plantacids: Reactions of lemon juice with lime (before 1768); *"acidum tamarindi"* is identical with tartaric acid (spring 1770); lemon juice contains scarcely some alkali. Its reactions are very similar to those of tartaric acid (spring 1770); crystals from barberry juice (December 6, 1774); citrate of calcium (October 4, 1776); method to bring lemon juice to crystallization (April 2, 1784); preparation of citric acid (April 30, 1784)

Plantjuices: Crystallization of the essential salts of plantjuices (December 1, 1767); purification of plantjuices (August 30, 1776); lemonjuice and barberry juice contain potassium (March 10, 1780).

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[11]) Nordenskiöld (Scheele, p. 458) gives the following explanation: "Oxygen was called vitriolic air by Scheele probably because a precipitate of sulfurated iron is changed to iron vitriol by absorption of oxygen, or even more likely because he had gained the gas by treating pyrolusite with oil of vitriol, the old term for sulfuric acid."

Plants: The capacity of plants to develop roots and to grow in various gases and the effect exerted hereby by the plants on the gases (1770); mushrooms lying under water generate carbondioxide (1770).

Plantsubstances: Products of dry distillation of gum arabic (1770).

Potassium: Reaction of potassium sulfate to heat, possibility of evaporation (before 1768); reactions of tincture of antimony and caustic alkali with ammonium carbonate, alcohol, gum, sugar, olive oil, wax, suet, etc. (before 1768); melting of potassium carbonate and of potassium hydrate with coal (before 1768); glass-gall is potassium sulfate (before 1768); potassium bicarbonate, method of preparing an easily crystallizable product (March 28, 1768); impurities in potassium carbonate (November 21, 1774); effect of carbondioxide on potassium acetate (May 10, 1776); plants contain the alkali found in the plantashes before they are burnt (July 5, 1782).

Pyrogallic acid: By distilling of gallnuts an acid product very similar to *"flores benzoini"*, i.e. benzoic acid, is obtained (spring 1770).

Pyrophor: The residue after the distillation of lead acetate and copper acetate if still warm ignites upon exposure to air (November 2, 1781).

Pyrotartaric acid: Products of repeated distillation of tartar (November 21 and December 26, 1774).

Rhubarbearth: The constituents of rhubarbearth (January 17, 1775).

Saccharic acid: Mention of saccharic acid (March 29, 1776).

Saltpetre: Decomposition of saltpetre if melted with coal (March 28, 1768); preparation of nitrogen from saltpetre and attempt at explanation of the formation of saltpetre (February 9, 1780).

Salts: Many acids form basic as well as neutral salts; examples for this statement (December 1771).

Silicic acid: Soluble alkali silicate (before 1768); decomposition of silicates by melting them with three parts of alkali carbonates (before 1768); silicic acid is insoluble in sulfuric acid (January 1773); glass and sand are not able to drive out hydrochloric acid of sodium chloride (January 25, 1773); silica seems to be able to be combined with phlogiston, i. e. to be reduced (January 1773); silica represents an acid (1773); silica is soluble in much water and is regained from its solutions by drying (January 1773 and January 27, 1780); basic silicates are decomposed by acids (March 1, 1773); silica does not combine with ammonia. It is precipitated by the latter (March 1, 1773); melting of silica with alkali before the blow pipe (May 10, 1773).

Silver: Silver chloride is not blackened by moonlight (before 1768); silver nitrate is reduced by heating without the presence of coal (March 28, 1768); by heating of silver carbonate metallic silver remains while oxygen and carbondioxide generate (1771/72); silver chloride is blackened most rapidly by the violet part of the spectrum. The blackening becomes slower in the proportion in which red rays form the spectrum. In daylight silver chloride is reduced and blackened even if it is covered with water (November 1775); solubility of silver chloride in a solution of mercury nitrate (1776); precipitation of silver nitrate by copper (1777).

Soap: Reactions of soap under certain conditions (before 1768).

Sodium: Preparation of sodium carbonate from sodium chloride from sodium nitrate, from Glauber's salt (before 1768); Glauber's salt deliquesces if triturated with potassium sulfate, or saltpetre, or magnesium sulfate or potassium carbonate (before 1768); burnt hartshorn contains sodium carbonate which can be edulcorated (before 1768); sodium sulfate and alcohol (before 1768); ash of oakwood contains sodium chloride and sodium carbonate (before 1768); preparation of sodium carbonate by filtration of a solution of sodium chloride through powdered litharge (before spring 1770); experiments proving that alumina does not contain sulfuric acid, that silica has to be considered an acid and that clay represents alumina saturated with silica. These experiments were made in investigating the reasons for the decomposition of sodium chloride if melted with clay (January 1773); distillation of sodium chloride with sand and magnesia alba as well as with sand and iron oxide and finally with sand and lime without obtaining hydrochloric gas (March 1, 1773).

Starch: Preparation of starch from wheat (September 6, 1774).

Stones: Stones consist of absorbent earths, saturated or supersaturated with silicic acid (January 1773).

Sugar: Sugar deliquesces with ammonium chloride and various other salts (before 1768 and February 8, 1777); reaction of sugar with various salts (spring 1770); action of pyrolusite and sulfuric acid or nitric acid on sugar (1771/72); the form of sugar crystals can be defined correctly in examining small and not large crystals (September 6, 1774); sugar can be transformed into honey but not honey into sugar (February 9, 1777).

Sulfur: Preparation of white *lac sulfuris,* i.e. precipitated sulfur, from *hepar sulfuris* (before 1768); varying color of a solution of alkali sulfide at different temperatures (before 1768); *hepar sulfuris* is obtained by heating alkali with sulfur, or alkali sulfate with coal, iron, or zinc (before 1768); gases generating if sulfur is distilled with oils (1770); evolution of heat if sulfur and iron or sulfur and lead are melted together. If sulfur is melted with iron oxide or lead oxide no heat evolves (November 1775).

Sulfuric acid: Concentrated sulfuric acid yields with oxide of nitrogen an icelike compound (before 1768 and March 28, 1768); reaction of sulfuric acid with organic substances (before 1768); reactions of sulfuric acid if heated with alum and coal (before 1768); solid sulfuric acid (March 28, 1768); anhydrous crystallized sulfuric acid (spring 1770).

Sulfurous acid: The acid is prepared from a solution of sulfur in alkali by means of mineral acids not plantacids (before 1768); sulfurous acid forms with carbondioxide and lime a readily soluble salt

(1770); sulfurous alkali absorbs a part of the air thereby being changed to alkali sulfate. The non absorbable part of the air does not support combustion (1770); conditions for the oxidation of sulfurous acid to sulfuric acid (April 16, 1775).

Sunlight: Sunlight contains phlogiston (November 1775).

Tartaric acid: Preparation of tartaric acid by treating tartar with chalk and sulfuric acid (before 1768); reaction of iron filings and litharge on tartar if boiled together (before 1768); "a white earth" (tartaric acid) found as an impurity in Seignette salt (before 1768); reactions of tartar with chalk; tartar consists of vegetable alkali and tartaric acid (before 1768); calcium tartrate (before 1768); composition of tartar; isolation of tartaric acid and reactions of the latter (spring of 1770); composition of Seignette salt (spring 1770); reactions of tartar with lime (February 28, 1774); contrary to the assumption of some chemists, tartaric acid is a specific acid and not a modified hydrochloric acid (November 21, 1774); potassium calcium tartrate (March 29, 1776); double salts of tartaric acid with calcium and baryum (May 10, 1776); double salt of tartaric acid with alkali and copper axide (May 24, 1776).

Tungsten: Tungstic acid attracts calcium more than does molybdic acid (January 8, 1780); melting of Scheelite, i.e. native calcium tungstate, with potassium carbonate (January 8, 1780); examination of Scheelite resulting in the statement of the presence of a specific acid (August 18, 1780); tungstic acid is very similar to molybdic acid but nevertheless different (October 20, 1780); the contents of Scheelite (November 13, 1780); tungstic acid, like molybdic acid, requires much water for its solution (February 26, 1781).

Turpentine: The residue after the distillation of turpentine is soluble in alcohol (before 1768); reaction of turpentine with lime (before 1768); turpentine if treated with sulfuric acid yields carbondioxide and sulfurous acid (1770); resinlike substance obtained by action of fuming nitric acid on turpentine (1771/72); reaction of turpentine with hydrochloric acid (November 23, 1777).

Urine: Investigation of the sediment of urine (1776 and February 9, 1777); preparation of uric acid and the reactions of the latter (October 26, 1776).

Vitriol (Sulfates): Separation of iron and zinc vitriol (April 16, 1775).

Vivianit (natural Prussian Blue): Reactions of vivianit (1771/72).

Wax and suet: The effect of turpentine on wax and suet (before 1768); from oil of wax a crystalline substance can be obtained (January 25, 1777).

Wheat: Distillation in order to examine wheat as to a supposed content of phosphorus (April 18, 1775).

Zeolite: Contents of zeolite (1770 and January 1773); distillation of zeolite with sodium chloride (January 1773).

Zinc: Reactions of zinc if dissolved in acids (before 1768); zinc is soluble in melting potassium hydrate or sodium hydrate (before 1768).