Chapter 2
Important Figures in Analytical Chemistry from Germany: From the Middle Ages to the Nineteenth Century

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The Period of Alchemy and Assay Analysis

The earliest recorded analytical methods are those for the precious metals of gold and silver. Of major importance for later assayers are the detailed and beautifully illustrated accounts of fire assay by Agricola and by Ercker in the sixteenth century.

ALBERTUS MAGNUS Saint, was Albert von Bollstädt, commonly known as Albertus Magnus (the English translation of which is Albert the Great,) (born ca. 1200 Lauingen, died 15 November 1280, Cologne) [1a, 2, 3, 4] (for portrait see Fig. 2.1). Albert's principal importance derives from the role he played in bringing Aristotle back to preeminence by making his writings readily accessible with detailed discussions and explanations and introducing Greek and Arab science into the universities of the Middle Ages. He studied liberal arts at Padua and in 1223 joined the Dominican Order, became bishop of Regensburg in 1260 but relinquished this post in 1262 to be able to devote more time to study. The latter part of his life was spent in preaching and teaching mainly in Cologne. He was canonized in 1931 and declared patron of all who cultivate the natural sciences in 1941. Thomas Aquinas was one of his most important students [1b]. Albert wrote a large number of works dealing with theology, minerals and natural history, which in time appeared in printed form and now are conveniently available in various editions of *Opera Omnia* [5, 6]. He included sections on chemical practices and alchemy in *De Mineralibus* [5a, 7] and was aware of the frauds of alchemists. Albert was interested in alchemical theories, but was not convinced of the alchemist's claims to make gold as he had not observed it being carried out and realized that chemical explanations were needed for many natural phenomena. Albert was probably the first to use the term "affinity" in the sense of chemical relation or attraction; sulphur burns metals because of its affinity. He knew how to carry out the cupellation procedure and the cementation process for the separation of silver and gold. When having some alchemical gold, which had come into his possession, tested it was found that after several firings, it was reduced to dross. Despite

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Fig. 2.1 Title page to *liber secretorum* (1502) [10] showing a portrait of Albertus Magnus with his students

the lack of evidence of Albert's direct participation in alchemical procedures, not long after his death, he acquired fame and repute as a skilled alchemist and his name has been attached to numerous Latin [4a] and English tracts on alchemy [8]. Most of his genuine works were republished numerous times prior to the collected editions. In his "Book of Secrets" [9–12], in the section on stones he described the physical properties, mythical (occult) attributes and sources of minerals such as asbestos, magnetite and onyx [4b]. On his travels, he made frequent side trips to mines and excavations to learn by observation the nature of metals and also to collect samples and was also aware of much contemporary chemical technology [4c].

Georgius Agricola latinized from his German name Georg Bauer, (born 24 March 1494, Glauchau; died 21 November 1555, Chemnitz) was probably the most important and influential technical writer of the sixteenth century [13, 14]. He was educated in classical languages at the Universität Leipzig and became a lecturer there (1522–1524). For the next 4 years, he studied at the universities of Bologna, Venice and, probably, Padua and obtained a medical degree. In 1527, he settled as town physician at Joachimsthal in Bohemia (now Jáchymov/Czech Republic). He spent his free time visiting mines and smelters and reading Greek

Fig. 2.2 Agricola's illustration of the acid parting of gold and silver [16]. A—Ampullae arranged in the vessels. B—An ampulla standing upright between iron rods. C—Ampullae placed in the sand which is contained in a box, the sprouts of which reach from the opercula into ampullae placed under them. D—Ampullae likewise placed in sand which is contained in a box, of which the sprout from the opercula extends crosswise into ampullae placed under them. E—Other ampullae receiving the distilled aqua and likewise arranged in sand contained in the lower boxes. F—Iron tripod, in which the ampulla is usually placed when there are not many particles of gold to be parted from the silver. G—Vessel

and Latin authors referring to mining. He resigned in 1530 and spent the next 2–3 years in study and travel. About 1533, he became town physician of Chemnitz in Saxony, where he remained until his death in 1555.

Agricola was the author of several books beginning with *Bermannus* in 1530 [15] and culminating in his famous *De Re Metallica* in 1556 [16–18]; the book was finished in 1550 but delayed in publication due to the slow preparations of the wood-block illustrations for which the book is justly famous. The Seventh Book describes in detail the method of assaying ores by cupellation and acid parting (see Fig. 2.2 for illustration of the process), the preparation and purification of reagents and cupels, and how to test if coins are good or debased using a touchstone [19]. Detailed procedures were given for preparing the touch needles and of the balances and weights in common use at the time. The descriptions of mining and the extraction and assay methods were based on the *Bergbüchlein* and *Probierbüchlein*, the earliest known was by Ulrich Rülein von Calw, Augsburg, 1505, (most editions are anonymous), on mining and assaying, respectively, published in the early sixteenth century [20].

Lazarus Ercker also known as Erckner or Erckel, (born ca. 1530 Annaberg; died 7 January 1594, Prague) was born in the Saxony mining town of Annaberg and educated at the Universität Wittenberg [21–23, 24I]. He became an assay master at an early age, about 25, and then became warden of the mint at Goslar in 1558. After his wife's death in 1567, he returned to Dresden but failed to find a post. He then went to Prague and with his brother-in-law's support was appointed control tester at Kuttenberg in Bohemia (now Kutná Hora/Czech Republic). In 1574, he published his now famous and well-illustrated text, *Beschreibung der allerfürnemisten Mineralischen Ertzt und Bergwerksarten* [25], which made use of material from Agricola's *De Re Metallica* omitting the discussion on mining, but giving much more precise, detailed and practical assaying methods. It included laboratory equipment and procedures, how to prepare cupels, constructing furnaces, making and adjusting assay balances and described only procedures he himself had tested. His contemporaries praised his work and Emperor Rudolf II knighted him in 1586, with grant of a coat of arms bearing a most appropriate device, *Erst prob's, dann lob's* ("Test it first, then praise it"). It appeared in eight editions in German, one in Dutch and two in English [26, 27]. The first English edition was that translated by Sir John Pettus, published with the title, *Fleta Minor* [26], a punning reference to the Fleet Prison where Pettus was incarcerated for the final years of his life and where he did the final writing. Pettus was imprisoned "through the accusations of an unscrupulous woman", his wife [27a, 28]. The early German editions all used the original blocks, gradual and slight deteriorations are evident in the later editions [29, 30], and however, for the Pettus edition, the 44 illustrations were redrawn, with the men in English dress of the period.

The Period of Iatrochemistry and Early Examples of Analyses in Solution

Basil Valentine or Basilius Valentinus, supposedly was a German Benedictine monk of Erfurt, born in Mainz in 1394 (for portrait see Fig. 2.3). The many publications attributed to him misled and perplexed chemists for many years until the position was clarified by Partington [31, 32]; the attributions must be false as the works refer to events that took place after his death. The real identity of Valentinus is now thought to rest with Johann Thölde, a chemist and owner of a salt works who first published the Valentine treatises during the period 1602–1604 [33]. The actual author(s) was very familiar with laboratory preparation, assay and some precipitation procedures, mining techniques, the then known metals, and in particular with the preparation of many compounds of antimony and the mineral acids. His most famous book, *Triumph Wagen Antimonii* (The Triumphal Chariot of Antimony) [34] is important as it contains a wealth of information on antimony and its ores. This book was the primary source for the many antimonial compounds used by seventeenth century Paracelsian or chemical physicians.

Fig. 2.3 Portrait of Basil Valentine

Andreas Libavius his given name was Andreas Libau but he is more well known under the Latinized Libavius (born ca. 1560 Halle/Saale; died 25 July 1616, Coburg) studied first at the Universität Wittenberg [24I] and then at Jena [24II] where he was graduated in medicine [35–37]. He occupied several teaching posts and was town physician in Rothenburg ob der Tauber, 1591–1607, before becoming director of the *Gymnasium* (academic high school) at Coburg in 1607, where he died in 1616. He was an enthusiastic chemical practitioner and author of numerous works on chymistry, religious matters and on education. He was not blind follower of Paracelsus and carried on controversies with both Paracelsists and Galenists. Libavius was an exponent of the iatrochemical trend in medicine; as a result, the application of chemicals was stressed in his writings. He was among the first to describe chemicals and their reactions in clear plain language. His most famous work, *Alchemia* (1597), is clear and systematic and has been described as the first systematic textbook of chemistry [38]. The enlarged edition, *Alchymia* (1606), in folio format [39], is beautifully illustrated, with 200 woodcuts, showing various sorts of chemical glassware, vessels, furnaces as well as architectural plans for the building of a *domus chymici*, a complete chemical institute containing numerous laboratories, store rooms, a library, study rooms and living quarters which was never built. Although sceptical of alchemy as a practical art, Libavius was knowledgeable of alchemical lore and symbolism such as the "Vase of Hermes", shown in *Alchymia* (1606).

Libavius is one of the founders of chemical analysis. He paid special attention to the analysis of mineral waters [38a], investigating those at Rothenburg ob der Tauber [40] and at Coburg [41]. He described many analytical reactions in solution, including that of iron with infusion of galls, the darkening of the blue of copper vitriol by addition of *spiritus urinae* (ammonia), and the darkening of solutions of lead, silver or copper salts with sulphur vapours (H_2S). He was aware of a volatile acid present in acidulous waters. He determined the quantities of dissolved salts by evaporation and examined the shapes of the crystals obtained, to identify alum, vitriol or saltpetre. He also dealt with the tastes, specific gravity, colours and odours of mineral waters and their medicinal uses, both internally and as baths.

Although Libavius travelled very little, he maintained contacts with many natural philosophers and read a great deal. In *Alchemia* (1597), he listed Edward Jorden first among certain friends, including Tycho Brache, who offered him information for his book, they met, whilst Jorden was a student on the continent. Jorden was the first to use acid–base indicators when examining mineral waters [42]. In his text on mineral waters, *Discovrse of Natvrall Bathes and Minerall Waters* [43], Jorden leaned on Libavius and cited him at least 17 times; a typical example of how Libavius' books were in use and cited by chemical practitioners throughout most of the seventeenth century.

Johann Rudolph Glauber (born 10 March 1604, Karlstadt; died 16 March 1670, Amsterdam) was a self-educated practical chemist [44, 45] (see Fig. 2.4 for portrait). He read, travelled and worked in Germany, Austria and Switzerland and obtained an extensive knowledge of chemistry, alchemy, pharmacy, mineralogy and their associated technologies. Glauber went to Holland in 1646 and settled in Amsterdam in 1648 where he had a large laboratory and prepared materials for sale. In his writings, he often extols his preparations in an exaggerated manner. In 1649, he returned to Germany, and in 1651, he set up a laboratory in Kissingen. He returned to Amsterdam around 1655 and set up another large laboratory. Over the years, Glauber prepared and described a vast range of inorganic and organic compounds, and was expert in the manufacture of the mineral acids and improved and invented numerous kinds of furnaces and stills. He was influenced by Paracelsus in his theoretical views and believed in alchemy as seen in the some titles and passages in his works [46]. Glauber wrote his works in German but with titles in Latin, most of his numerous works were published in Holland; many were regarded as important at the time as the various Latin, English and French translations of individual book and of compilations demonstrate. His most important

Fig. 2.4 Portrait of Johann Rudolf Glauber (1604–1670) by Anthonius Santvoort (1654 AS). The inscription round the portrait reads (translated), "True portrait of the honoured and highly esteemed Johannis Rudolphi Glauberi Noble chemist and experimenter at Kitzingen in Franconia"

work is *Furni novi philosopici.* (New Philosophical Furnaces) [47, 48], a book, written with clarity, which established his reputation, as a master of laboratory skills. In the Preface to the English translation of collected works [49], Packe said the Latin works were then very scarce and expensive in London. He purchased the copperplates in Amsterdam with the legends in German. Packe knew no German so he translated the Latin works. His list of subscribers included Robert Boyle and William Penn.

Glauber made significant contributions to dry and wet tests for qualitative analysis. He described the characteristic colours given by metals when fused with fusible Venice glass (a precursor to the borax bead test), the coloured precipitates given by solution of salts of metals with ammonia and with salt of tartar (potassium carbonate), paid attention to crystal forms, he also dealt with assaying.

Fig. 2.5 Portrait of Johann Kunckel (1638–1703), from *Ars vitaria* [49]

Johann Kunckel (born ca. 1630 Hütten, Schleswig; died 20 March 1703, Stockholm), was awarded Swedish nobility in 1693 under the name **Johann von Löwenstern-Kunckel** [24a, 50, 51] (see Fig. 2.5 for portrait). He was the son of an alchemist and had no university education and learned chemistry from his father and practical chemistry from pharmacists and glassworkers. He eventually became pharmacist to the Duke of Saxe-Lauenburg, later to the Elector of Saxony; he lost this post and then taught at the Universität Wittenberg [24I]. In 1679, he went to the court of Friedrich Wilhelm, Elector of Brandenburg. On the elector's death in 1688, he entered the service of King Charles XI of Sweden as Minister of Mines and was ennobled in 1693 as Baron von Löwenstern.

Kunckel's chemical views derived from alchemy crossed with rational philosophy. Whilst he despised alchemists for their mysticism, he inclined to regard their aims as rational. He was a very able practical chemist who made, in his times, significant contributions to chemical analysis, including dry and wet reactions via blowpipe analysis and early gravimetric methods. His interest in the use of a blowpipe came from his studies of glass manufacture. He described how metal oxides may be reduced on charcoal with a flame. He carried out many quantitative experiments and described in his most important work *Laboratorium Chymicum* [52] some were remarkably accurate, for example, he says when 12 parts of silver were dissolved and precipitated with common salt or *sal ammoniac* (NH_4Cl), this gave exactly 16 parts of silver chloride, which is close to the theoretical value of 15.95 [52a].

Although Kunckel knew some Latin, he wrote his works in German, giving many of them Latin titles as was then customary. Partington lists his numerous works, their various editions and translations [50a]. Best known, and read for the next century, was a series of essays on aspects of glass making, *Ars vetraria experimentalis* [53]. This was a translation into German of Christopher Merret's Latin edition of Antonio Neri's *L'arte vetraria* of 1612 [54a]. Kunckel kept Merret's notes and added further notes as well as a section on the making of coloured glass. Its translation into French in the mid-eighteenth century added considerably to his reputation [55]. Kunckel perfected the art of making ruby glass [52, 53], by suspension of gold, the nature of which still excites scientific interest [56].

Kunkel was also important in the history of the discovery of phosphorus and shares with Robert Boyle the honour of discovering the secret of the process by which Hennig Brand of Hamburg had prepared phosphorus. Having obtained a hint from Brand during a visit to Hamburg in 1675 that it was made from urine, he returned to Wittenberg and by July 1676 had prepared half an ounce of solid white phosphorus. He published an account of his phosphorus and its medical properties, but not its method of preparation [52, 57–59], and this was first published by Boyle [60].

Both Davis and Partington regarded Kunckel as one of the most competent chemists of the seventeenth century, an able experimenter and an acute observer with great patience and stubborn application—the qualities found in a great chemist.

Otto Tachenius also called Tachen and Tackenius (born ca. 1620 Herford, Westphalia; died ca. 1680 Venice), details of his life are obscure and mainly come from statements by his protagonists such as Helwig Dietrich (over a letter on the alkahest) and Johann Zwelfer (over the invention of the viperine salt) [61–63]. He is said to be the son of a miller and a former abbess, and he was apprenticed to a pharmacist at Lemgo but dismissed for theft, then acted as assistant to pharmacists in Kiel, Danzig (now Gdańsk/Poland) and Königsberg (now Kaliningrad/Russia). In 1644, he went to Italy and in 1652 obtained an M.D. from Padua and then settled in Venice. He was a passionate and provocative man and involved in many scientific polemics and in disputes with authorities. His works were published in Venice from 1655, the most important being *Hippocrates Chimicus*, *Per ignum et aquam Methodoinaudita Novissimi Salis Viperini…* [64, 65] and *Antiquissimæ Hippocraticæ Medicinæ Clavis Manuali experientia in Naturæ fontibus elaborate* [66]. Tachenius was introduced into Italy the hypothesis of acid and alkali as the basis of physiology and pathology. He was a good chemist with a clear understanding of reactions and a wide knowledge of substances and their preparation, for example, when discussing the manufacture of soap, he noted that fats contain a hidden ("occult") acid [65a].

Of the many extant analytical notes of Tachenius, one of the most interesting is that of his systematic examination of the effect gall-nut extract on metal salt solutions, given by Nierenstein from the 1677 English translation of *Hippocrates*

Chimicus [65b] in *Incunabula of Tannin Chemistry* [67] and discussed later by Szabadváry [68] who regarded Tachenius as, "a somewhat neglected figure in the history of chemistry". Tachenius recorded the colour formed by various metals and established that iron was not removed from the human body via the urine as previously supposed, as no colour was obtained when urine was treated with gall-nut extract. An early, if not the first, example of analysis applied to biochemistry.

Another interesting applied analysis is Tachenius' examination of samples of rose water, used at the time to prevent ascarides [65c]. It was found that certain samples taken internally for this purpose caused the patients to vomit. Tachenius examined the problem and found that it was not due to the rose water *per se*, but due to copper contamination which came from the copper flasks used in its preparation. If a few drops of alkali are added to the rose water, a green precipitate forms; after filtering, the rose water did not cause vomiting. When the green precipitate was fused with borax, it showed the presence of copper.

Friedrich Hoffmann (born 19 February 1660, Halle/Saale; died 12 November 1742, Halle/Saale) was the son of a physician of the same name [24b, 69–71] (for portrait see Fig. 2.6). From 1678, he studied medicine at Jena under Wolfgang Wedel, and chemistry with Caspar Cramer in Erfurt [24III] and graduated M.D.

Fig. 2.6 Portrait of Friedrich Hoffmann (1660–1742) from his *Opera Omnia Physico-Medico* (1740)

at Jena in 1681. He then travelled extensively, and whilst in England, 1684–1685 became acquainted with Robert Boyle [72]. In 1685, he commenced medical practice and his reputation grew rapidly. In 1693, he was appointed the first Professor of Medicine at the new Friedrichs-Universität Halle/Saale [24IV]. His lectures on physics, chemistry, anatomy, surgery and medicine attracted great numbers of students from all over the world. He worked at the university for 48 years. From 1709 to 1712, he was personal physician to Friedrich I, King of Prussia, but as he preferred the scientific to court life and returned to his professorship, but returned to court in 1734 for about 8 months. He received numerous honours and academy memberships including Fellowship of the Royal Society of London. Although his main contributions were to medicine, he maintained a lifelong interest in chemistry. Hoffmann made major contributions to the investigation of mineral waters, specifically by significantly improving on the contemporary analytical methods and by distinguishing essential components. Hoffman studied carbon dioxide (called *spiritus mineralis*), which he described as a weak acid intermixed with several salts. He noted the presence of sulphates in certain waters, detected rock salt with *lunar caustic* (silver nitrate), copper by precipitation with iron, separated magnesia from lime and described the manufacture of artificial mineral waters. Essays on the examination of mineral waters are included in several of his medical works and were discussed in detail in *De method examinandi aquas salubres* [73]. This text was followed by numerous accounts of specific mineral waters sources and their contents. Hoffmann's numerous contributions were collated and translated, by Shaw [74].

The Phlogiston Period

Georg Ernst Stahl (born 22 October 1659, Ansbach; died 14 May 1734, Berlin) studied medicine at the Universität Jena, which was at the time a stronghold of iatrochemistry, stressing the unity of chemistry and medicine and the application of chemistry in medicine, and graduated in 1684 [75–77] (for portrait see Fig. 2.7). He taught chemistry for awhile at Jena, in 1687 was appointed court physician to the Duke of Saxe-Weimar and in 1684 moved to the new Friedrichs-Universität Halle/Saale. He left Halle in 1715 to be court physician in Berlin to Friedrich Wilhelm I of Prussia. As noted by Partington, Stahl was a prolific author [76]. He is principally remembered for his part in the development of the phlogiston theory following on from the earlier work of J. J. Becher about the combustible component or principle of bodies *terra pinguis* (oily earth), which Stahl called phlogiston. The phlogiston theory [78] was the first systemizing chemical theory and lasted most of the eighteenth century until experimental evidence mounted against it, culminating in the chemical revolution, and Lavoisier's explanation of the role of oxygen in combustion. Stahl also made considerable progress on the properties of salts and the concept of an affinity series for metals, fractional crystallization and concentration of solutions by freezing.

Fig. 2.7 Portrait of Georg Ernst Stahl (1660–1734)

Andreas Sigismund Marggraf (born 3 March 1709, Berlin; died 7 August 1782, Berlin) was one of the most famous and experimentally adept chemists of the phlogiston period; his interest in chemistry for its own sake, his refinement of analytical tools and his use of the balance anticipated some facets of the chemical revolution and the demise of the phlogiston theory [24c, 79–81], (see Fig. 2.8 for his portrait).

He was the son of a court apothecary; from 1725 to 1730, he was a pupil of Caspar Neumann at the court pharmacy. He later studied at the universities of Straßburg (now Strasbourg/France) [24V] and Halle/Saale [24IV]. In 1734, he travelled to Freiberg to the Mining Academy [24VI] to study chemistry with Henckel and assaying with Süssmilch. In the spring of 1735, he returned to Berlin to work with his father in the Berlin court pharmacy. In 1738, he became a member of the Kurfürstlich Brandenburgische Sozietät der Wissenschaften (Electoral Brandenburg Society of Sciences, now Berlin Brandenburgische Akademie der Wissenschaften) [24VII]; in 1753, he became Director of the Academy's

Fig. 2.8 Portrait of Andreas Sigismund Marggraf (1709–1782)

new chemical laboratory and from 1760 Director of its Class of Experimental Philosophy. Many of his papers were published in the journals of the Berlin Academy and are available as collected works in German [82] and in French [83].

Marggraf's earliest publications are on phosphorus and its compounds. He recorded that 1 oz increased in weight by 3½ drahms when burnt. He made numerous advances in inorganic analysis, by purifying reagents, examining the effects of alkalis on metals and their salts, using a microscope he could distinguish between "cubic nitre" (sodium nitrate) and "prismatic nitre" (potassium nitrate) and that they could also be distinguished by a flame test using a blowpipe. He designated sodium salts as "mineral fixed alkali" and potassium salts as "fixed vegetable alkali". He pioneered the use of the reagent potassium hexacyanoferrate (formed from cattle blood ignited with alkali) as a sensitive reagent for iron in a variety of samples. Many of his tests were used systematically as, for example, in his essay on the chemical examination of water.

He also published several memoirs on plant and animal chemistry, for example, characterizing the acid extracted from ants (formic acid), examining the "essential oil" from cedar wood, the most important was his discovery using microscopy, that beet sugar was identical to cane sugar [84].

Marggraf worked with quite small amounts of materials, compared to his contemporaries. His papers are models of concise, rigorous and systematic experimentation with little speculation beyond the conclusions which the observations seemed directly to establish.

Johann Andreas Cramer (born 14 December 1710, Quedlinburg; died 6 December 1777, Berggieshübel near Dresden) was the son of the leaseholder of the state ironworks in Quedlinburg who introduced him to metallurgy [24d, 85–87]. After secondary school, Cramer at first studied law at Hamburg, then medicine at Halle/Saale [24IV], which he abandoned as anatomy made him sick. He returned to law, but continued to study chemistry. In 1729, he proceeded to Academia Julia (Julius-Universität) Helmstedt [24VIII], where he spent about 1 year. He then started to practise law in the mining town of Blankenburg (then Principality of the Empire, now in Saxony-Anhalt). In his spare time, he pursued chemistry and metallurgy to an extent that he was described as "black Cramer". In 1734, he returned to Helmstedt and then to Leiden to study medicine where he also taught analytical chemistry. Whilst at Leiden, Cramer worked on a textbook, the first of its kind, *Elementa artis docimasticae*, published in 1737 [88]. This text appeared in several editions and was translated into several languages including English [89, 90]. Both editions were produced by the printers to the Royal Society and over the years and brought him international recognition. In his book, Cramer described all the instruments and apparatus of contemporary analytical chemistry, explaining in detail the construction of an accurate and sensitive balance. Although Cramer's book was designed as an introduction to the trade of assaying, he believed that assaying could contribute to the pursuit of natural knowledge. Cramer classified minerals by the use of blowpipe tests on a charcoal block and by borax bead tests.

He visited England in 1738 and 1739 to learn more about metallurgy and assaying and lectured on the subject in London. After further travels, he returned home and was appointed director of the Brunswick Mining and Metallurgy administration, a post he lost in 1773 by the actions of his enemies. In 1774, he accepted a new post in Saxony, and he was consultant to the Habsburg Mining Administration in Hungary from 1775–1776. He returned to Germany in 1777 as consultant to the Saxon Mining Administration, but died later that year. Although barely mentioned by Szabadváry, Partington states he was the best assayer of his time. Recently, Cramer's contributions to assaying in the eighteenth century have been reassessed [91, 92].

Heinrich Johann Lambert (born 26 August 1728, Mülhausen/Elsass, now Mulhouse/France; died 25 September 1777, Berlin) grew up in impoverished circumstances and by self-education became a noted mathematician and physicist [93] (for portrait see Fig. 2.9). Although not a chemist, his name is well known to analytical chemists by his name being associated with the law that governs the absorption of radiation by matter, commonly called the Beer–Lambert (in Germany: Lambert–Beer) law [94].

Fig. 2.9 Portrait of Johann Heinrich Lambert (ca. 1728–1777)

Lambert's book, *Photometria* [95], that deals with optical measurements was published in 1760. In it, he stated:

> If a light beam with an intensity I passes through a layer [in his experiments, of glass] of width l, its intensity will decrease to $I \times 1/n$ of its original intensity while if it passes through a further similar layer its intensity will decrease to $I \times 1/n \times 1/n$ of its original value. For m layers the intensity of the exiting light will be $I' = I/n^m$.

He also noted:

> The amount of captured light is the greater, the greater the number of particles within a given volume and the larger the surface area of a given particle.

Later, in 1852, Beer pointed out that the Lambert law also applied to solutions and defined the absorption coefficient [96].

The Beer–Lambert law could equally be described as the Bouguer–Bernard law. Bouguer's research predated but was unknown to Lambert, his *Essai* [97] was published in 1729. Bernard also defined the absorption coefficient, a few months after Beer [98].

The Demise of Phlogiston and the Rise of Stoichiometry and Quantitation

Carl Wilhelm Scheele (born 19 December 1742, Stralsund; died 21 May 1786, Köping, Sweden) is normally listed as a Swedish chemist but is included herein because Stralsund is in Western Pomerania, then a Province of Prussia, although

Fig. 2.10 Portrait of Carl Wilhelm Scheele (1742–1786)

at the time, it was temporarily under Swedish rule [99–102]. He began his career at the age of fourteen by a pharmacy apprenticeship with B.A. Brauch in Gothenburg (for portrait see Fig. 2.10). He occupied positions in pharmacies in Malmö, Stockholm, Uppsala and Köping. Scheele was a man of great modesty, often in poor circumstances, who was more interested in doing research on chemicals rather than producing them for sale. In Uppsala, he became acquainted with T.O. Bergman, from whom he received advice and encouragement. Scheele made a great number of important chemical discoveries including those of the elements chlorine, fluorine, manganese, molybdenum, tungsten and oxygen. Those on air and combustion, he published in …*Luft und dem Feur*…(1777) [103], which not only brought him to the attention of Priestly and Kirwan in London [104] but that of Frederick the Great as well. The latter wanted him as successor of the diseased Andreas Sigismund Marggraf at the Kurfürstlich Brandenburgische Sozietät der Wissenschaften (Electoral Brandenburg Society of Sciences, now Berlin Brandenburgische Akademie der Wissenschaften), but his plenipotentiary was not able to find him [105].

Most of Scheele's other studies were published in the proceedings of the Royal Academy of Sciences in Stockholm [106] of which he became a full member in 1775. Due to his significant achievements in inorganic chemistry, those in organic chemistry are often overlooked. He was the first to isolate and characterize a large number of organic acids such as tartaric, lactic, uric, citric, gallic, pyrogallic and malic acids. In 1776, he was able to establish his own pharmacy in Köping, which he purchased from the widow of the previous owner H. Pohl. On his death bed, Scheele married the widow Pohl, but passed away 48 hours later at the early age of 43, probably due to the toxic effects of the chemicals he had worked with.

Martin Heinrich Klaproth (born 1 December 1743, Wernigerode; died 1 January 1817, Berlin) was the son of a tailor, after leaving school at 15 became an apprentice pharmacist in Quedlinburg [24e, 107–109] (for portrait see Fig. 2.11). He later became an assistant pharmacist in Hanover, Berlin and Danzig (now Gdańsk/Poland). In 1771, he went to work in Valentin Rose's pharmacy in Berlin. Rose died 4 weeks after Klaproth had joined him. Klaproth continued to run the pharmacy and see to the education of Rose's two sons, one of them Valentin Rose Jr. became a chemist of note and in due time collaborated with him. In 1780, he married a wealthy niece of A.S. Marggraf and purchased his own pharmacy. Previously, he had carried out some research in addition to pharmacy; he then devoted himself almost entirely to research mainly on the analysis of minerals from all parts of the world.

Klaproth discovered or co-discovered zirconium, uranium, titanium, strontium, chromium and cerium and confirmed the prior discoveries of tellurium and beryllium. After confirming several of Lavoisier's experiments, he abandoned the phlogiston theory and was the first important German chemist to openly accept the

Fig. 2.11 Portrait of Martin Heinrich Klaproth (1743–1817)

views of Lavoisier. Klaproth introduced new techniques, fusion of finely ground insoluble mineral in alkali carbonates, decomposition of silicates by fusion with barium nitrate. He constantly drew attention to the necessity of avoiding or making allowances for contamination from apparatus and reagents. Most significantly he broke with the tradition of ignoring small losses and gains in weight in analytical work. He used the discrepancies, over a few percentage points as a means of detecting faulty and incomplete analyses. Once satisfied with his procedure for analysing a mineral, he reported his procedures in detail, with the final results including any remaining discrepancy.

Most of his numerous publications are in his *Beiträge* [110] and listed in the Royal Society Catalogue [111]. The first two volumes of *Beiträge* were translated into English [112] and the first three into French [113]. The advertisement to the English translation of volume I of his collected works neatly expressed Klaproth's reputation as follows:

> The merits of KLAPROTH, in Chemical Analysis, are so eminently established with men of science throughout Europe, that it would seem improper to enlarge on the most consummate skill and accuracy with which he performed his experiments, as well as on his laudable candour in stating their results.

The notice in volume II was equally fulsome in its praises. In addition to *Beiträge*, Klaproth wrote *Observations relative to the Mineralogical and Chemical History of the Fossils of Cornwall* [114] and with Benjamin Wolff, a good Dictionary of Chemistry [115].

Over the years, Klaproth moved up in the Prussian medical bureaucracy and in the Berlin Academy [24e, VII]. He received numerous honours at home and abroad, for example, in 1795 by election as a Fellow of the Royal Society of London. In 1800, Klaproth was appointed leader of the chemistry laboratory of Berlin's Academy (Königlich Preußische Sozietät der Wissenschaften). In 1803, he sold his pharmacy at a great profit and moved into the academy's new laboratory residence, where he worked until his death in 1817. After the founding of the Friedrich-Wilhelm-Universität (now Humboldt-Universität), Berlin he was appointed in 1810 to be the first Professor of Chemistry.

Lorenz Florenz Friedrich von Crell (born 21 January 1744, Helmstedt; died 7 June 1816, Göttingen) was the son of Johann Friedrich Crell, Professor of Medicine in the Academia Julia (Julius-Universität) of Helmstedt [24VIII], who died in 1747 [24f, 116, 117]. His early education was supervised by his maternal grandfather, Lorenz Heister who was also a Professor of Medicine in the University of Helmstedt. In 1759, Crell entered the local university, studied the philosophical sciences for 6 years and the medicine (see Fig. 2.12 for his portrait). During his medical studies, he was introduced to chemistry by G.C. Beireis. He was graduated M.D. in 1768. He then spent the next two and a half years on a study tour to Strasbourg, Paris and Edinburgh. During this trip, the men that influenced him most were William Cullen and Joseph Black, both in Edinburgh. Crell remained in contact and correspondence with Black [118], some letters were published [119] and he translated Black's *Lectures on the Elements of Chemistry* [120].

Fig. 2.12 Portrait of Lorenz Florenz Friedrich von Crell (1745–1816)

Soon after his return to Germany, he was appointed to the new chair of chemistry in the Collegium Carolinum (now Technische Universität) Brunswick in 1771 [24IX]. He was Professor of Philosophy and Medicine at the Universität Helmstedt from 1773 until its closure in 1810 by the Napoleonic regime, when he transferred to Göttingen [24X]. He is primarily remembered for his literary activity although he carried a number of original researches on inorganic materials and on natural products [121].

Over the years, Crell produced and edited a large number of journals [24f(i), 122], some were short lived such as his first, *Chemisches Journal* (1778–1781), translated into English as *Chemical Journal* [123], this was important as it was the first journal to be exclusively devoted to chemistry [124]. Some of his other journals such as *Chemische Annalen* (1784–1804) were more long-lasting. Crell published work by many distinguished analytical chemists such as Klaproth, Lowitz and Richter. Through his position as a successful journal editor, Crell was enabled to exert a strong influence on the German reception of the various theories being developed to deal with the then new area of pneumatic chemistry [24f(ii)]. At first, he supported Richard Kirwan's view that phlogiston was inflammable air (hydrogen) and continued to do so against the tide of opinion in the rest of the German chemical community. Interestingly, it was Crell who published Kirwan's conversion in 1791 to Lavoisier's views [125] nonetheless Crell remained a phlogistonist. Crell received numerous honours and awards from the major European scientific societies including in 1783 Fellowship of the Royal Society of Edinburgh, and in 1788, Fellowship of the Royal Society of London.

Johann Tobias Lowitz (born 25 April 1757, Göttingen; died 7 December 1804, St. Petersburg/Russia) was the son of Georg Moritz Lowitz who from 1762 was Professor of Mathematics in the Georg-August-Universität Göttingen [126–128] (see Fig. 2.13 for silhouette portrait). In 1767, his father was called to St. Petersburg as Professor and Member of the Imperial Academy of Sciences. In 1774, he and his father went on an Academy expedition to the shores of the Caspian Sea. They were captured by a band of rebels and his father was hanged, Tobias escaped and returned to St. Petersburg and was placed at the Academy Gymnasium. In 1776, he became apprentice to the Court Pharmacy. He then studied at universities in Germany. In 1787, he was appointed Court Apothecary. In the course of his work, he was called upon to prepare and purify many chemicals, and he became a talented and innovative chemist. One of his important discoveries was the use of charcoal to absorb visible impurities from many substances and gases [129]. Among his many analytical innovations [127] were the study of crystal

Fig. 2.13 Portrait of Johann Tobias Lowitz (1757–1804) drawn in St. Petersburg in 1799

form of salts under a microscope as a basis for their identification, the separation of calcium from barium based on the relative solubility of their chlorides in absolute alcohol, the colours alkaline earth metals impart to flames, the dissolution of silicates in hot caustic alkali solutions, an alternative to fusion, and a series of novel titrations of acetic and sulphuric acid [130]. His publications were mainly published in Crell's *Annalen* and *Nova Acta* of the St. Petersburg Academy [131] of which was elected an adjunct in 1790 and a full member in 1793.

Jeremias Benjamin Richter (born 10 March 1762, Hirschberg, now Jelenia Góra/Poland; died 14 April 1807, Berlin) after graduation from Hirschberg Gymnasium, he joined the engineering corps of the Prussian army in 1778 [24g, 132–135] (see Fig. 2.14 for his portrait). He devoted his spare time to studying chemistry. He left the army after 7 years and studied mathematics in the Königliche Albertus-Universität zu Königsberg in Preußen (now Kaliningrad/Russia) [24XI] and graduated as doctor in 1789, with a dissertation *De usu matheseos in chymia*, a clear indication of his future interests. He worked for a while near Glogau (now Głogów/Poland) and then in 1795 as assayer as secretary of the mining office at Breslau (now Wrocław/Poland), finally from 1798 as "second Arcanist" (chemist) at the Königliche Porzellan-Manufaktur (Royal Porcelain Factory) Berlin. Richter carried out research in his own time, mainly at night, and shaped by his firm conviction that all chemical processes are based on mathematical laws. His terminology is difficult to understand as he uses his own peculiar symbols instead of names for chemical substances and writes in a verbose style. Richter's results and their publication are clearly set out and explained by Partington [132].

Richter was the first to recognize the significance of the law of neutrality and establishes the basic rules of stoichiometry. The word stoichiometry originates from Richter, in his major work, *Anfangsgründe der Stöchyometrie oder Messkunst chymischer Elemente* [136]. In his series of experiments published between 1792 and 1802, he determined that the weights of various bases (lime, soda, baryta, potash and magnesia) which neutralized a given quantity of an acid was characteristic of the particular base. Likewise, the weights of different acids neutralized by a given weight of a certain base were characteristic of the particular acids. Richter's work was almost unknown and not appreciated until in 1802 E.G. Fischer, in a note to his translation into German of Berthollet's *Recherches sur les lois de l'affinite* [137] put Richter's results in tabular form, the weight equivalents of various bases that would neutralize 1,000 parts of sulphuric acid. The numbers assigned to the various acids show the weights of acids necessary to neutralize the same amount of any base as could be neutralized by 1,000 parts of sulphuric acid. This publication of the first table of equivalent weights made Richter's results widely and generally available. Richter made significant contributions to various areas of preparative chemistry [133], and it was not until the acceptance of Dalton's atomic theory that the significance of his studies in stoichiometry became fully recognized.

Fig. 2.14 Portrait of Jeremias Benjamin Richter (1762–1807)

The First Analytical Textbooks

Many guide books to assaying, such as those by Agricola, Ercker and the booklets, *Bergbüchlein* and *Probierbüchlein* [20], were published in the sixteenth century, although these were compiled for artisans rather than scientists. These were followed in the next century by texts dealing with the characterization of mineral waters. By the end of the seventeenth century, scientific textbooks of chemistry became available, however, they contained little specific analytical material. At the end of the eighteenth and early nineteenth century, the first books devoted to analytical chemistry appeared. Important examples are those by Lampadius, Pfaff and Rose.

Wilhelm August Lampadius (born 8 August 1772, Hehlen, now part of the district Holzminden; died 13 April 1842, Freiberg) after leaving school at the age of 13 he became apprenticed in Göttingen's Rats-Apotheke [24h, 138–142] (see Fig. 2.15 for his portrait). During his apprenticeship, he studied languages and natural sciences on his own, then began attending lectures at Georg-August-Universität Göttingen [24X] and meet J.F. Gmelin. In 1791, he finished his training as a pharmacist and began scientific studies in earnest. He worked closely

Fig. 2.15 Portrait of Wilhelm August Lampadius (1772–1842)

with G.C. Lichtenberg and J.F. Gmelin, serving as experimental assistant in their courses. Lichtenberg introduced him to his future employer, Count J. von Sternberg.

In 1792, Sternberg employed him as a travelling companion for an expedition through Russia to China. En route to Russia, he met M.H. Klaproth in Berlin. On arriving in St. Petersburg, he learnt that the Russian Government had denied permission for the expedition. He stayed awhile and met T. Lowitz, then accompanied Sternberg back to his Bohemian estates. Lampadius then established a new ironworks for Sternberg at Radnitz (now Radnice) near Pilsen. During this time, when A.G. Werner was seeking a successor to C.E. Gellert in the Kurfürstlich-Sächsische Bergakademie (Mining Academy) Freiberg [24VI], he interviewed him on Klaproth's recommendation. Favourably impressed, Werner recommended the appointment. Lampadius held the chair with great distinction from 1794 until 1842. In 1801, Lampadius published the *Handbuch zur chemischen Analyse der Mineralkörper* [143].

His methods were similar to those of Klaproth but parts of the book are in the style of textbooks of a much latter period. For example, it gives lists of equipment and apparatus required for analysis and instructions for their use. The introductory part deals with the preparation and purification of various reagents. These descriptions are the earliest record of standard methods used for the testing of the purity of analytical grade reagents, in many cases are very similar to current methods. The purity of distilled water was tested as follows:

1. Neither lead acetate nor heavy earth (barium) acetate should cause turbidity.
2. It must remain clear after the addition of silver solution.
3. It should show similar effect with potassium carbonate.
4. Similarly with potassium cyanide, and
5. Similarly with lime water.

Lampadius described the tests for the more important salts, and he did not realize that it was necessary to examine for metal ions and anions, this only became apparent after Berzelius's dualistic theory. In addition to gravimetric methods, he used titrimetric methods. His method for sodium carbonate with sulphuric acid using curcumin paper as indicator was absolute as he determined the amount of pure sodium carbonate equivalent to the acid consumed [141, 142b]. He made many discoveries in technical chemistry [144] and published major texts in this area in addition to those on the examinations of minerals. For example, he investigated the commercial production of sugar from beets and introduced gas lighting to Germany at the amalgamation works Halsbrücke (now part of Freiberg).

Christoph Heinrich Pfaff (born 2 March 1773, Stuttgart; died 23 April 1852, Kiel) came from a well off family his father being the General Treasurer of Württemberg [24i, 145] (see Fig. 2.16 for his portrait). He was tutored at

Fig. 2.16 Portrait of Christoph Heinrich Pfaff (1773–1852)

home, then he entered Hohe Karlsschule (Duke Carl's Academy) in Stuttgart in 1782, after 4 years of pre-university study. From 1786–1788, he studied in the Academy's philosophical section and from 1788–1793 in its medical section. From the mid-1780's, natural history was his chief enthusiasm.

It has been said that once introduced to chemistry, it became his favourite science. His MD thesis in 1793 was on animal electricity. He then went to Georg-August-Universität Göttingen to study obstetrics and also worked in J.F. Gmelin's laboratory. From 1795, he spent 2 years as personal physician to Count F. Reventlow, later his patron as Curator at the Universität Kiel. After a year in private practice in Heidenheim, he was then appointed as Assistant Professor in the Medical Faculty at Universität Kiel. In 1801, he went to Paris at government expense to prepare for the chair of chemistry, whilst in Paris, he met the leading French chemists of the day. From 1802–1846, he held the chair of chemistry and physics in the medical faculty. He was an extremely productive scientist dealing with topics in voltaic electricity, physics, botany and pharmacy, general and preparative chemistry, but above all, in analytical chemistry [146]. In addition to his numerous research papers and textbooks, Pfaff made a major and influential contribution to analytical chemistry by writing the first general and comprehensive two volume textbook, *Handbuch der analytischen Chemie für Staatsärzte, Apotheker, Oekonomen und Bergwerks Kundige* [147]. Szabadváry describes the contents and their significance in some detail, noting in particular, the lengthy section on the preparation of reagents, tests for their purity, detailed discussion of qualitative and quantitative gravimetric reactions of metals, and the book concludes with the analysis of gases and organic substances [148]. In view of Pfaff's considerable contributions, it is surprising that he only merited *en-passant* mentions by Partington and in the Dictionary of Scientific Biography.

Friedrich Stromeyer (born 2 August 1776, Göttingen; died 18 August 1835, Göttingen) was the son of J.F. Stromeyer, Professor of Medicine at the Georg-August-Universität Göttingen [149, 150]. He studied pharmacy at the university and so was influenced by J.F. Gmelin. He continued his studies in Paris with L.N. Vauquelin who was an exceptionally able analyst. Returning to Göttingen [24X], he graduated in medicine in 1800 (see Fig. 2.17 for his portrait). He then made a scientific tour and met many distinguished chemists; their accomplishments decided him to turn from medicine to chemistry. In 1802, he habilitated as *Privatdozent* (Assistant Professor) in pharmacy and chemistry. He made such progress that after Gmelin's death he was named extraordinary professor in 1805, the next year, the director of the chemical laboratory and in 1810 full professor. He wrote several textbooks on chemistry and published a considerable number of important investigations [151] most of which were analytical in nature, including the analysis of minerals and the use of starch to detect free iodine. In 1817, he discovered cadmium. Importantly, Stromeyer predated Liebig in the establishment, in 1805, of laboratory instruction for undergraduate students in chemistry [149].

Joseph Fraunhofer (born 6 March 1787, Straubing, Lower Bavaria; died 7 June 1826, Munich) although not a chemist, is worthy of mention herein, as exemplifying

Fig. 2.17 Portrait of Friedrich Stromeyer (1776–1835)

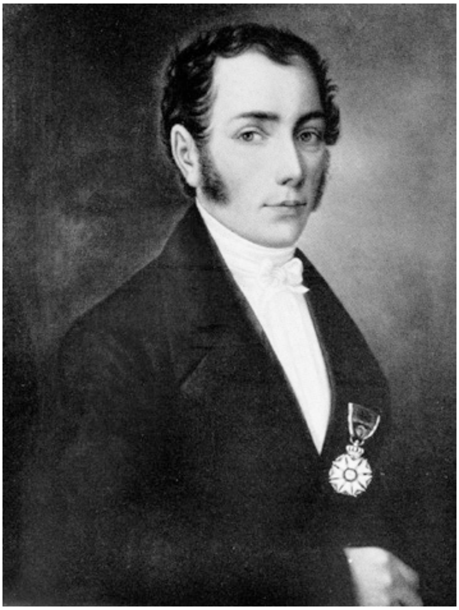

Fig. 2.18 Portrait of Joseph Fraunhofer (1787–1826)

the highest level of union between a craftsman and a theoretician (see Fig. 2.18 for his portrait). His activities permitted major progress in analytical chemistry via spectroscopy and his improvements to optical components, namely to glass for prisms, achromatic lenses and in the manufacture of diffraction gratings. He came from a poor family and received limited schooling, after the death of his father in 1798 became apprenticed to a glass polisher [152]. When the workshop house collapsed, he was buried under the ruins. Elector Maximillian Joseph heard of the accident was present at his extrication and presented him with sufficient money for release from his apprenticeship, purchase of a glass polishing machine and books on optics. After working as a journeyman, he then entered the firm of Utzschneider, Reichenbach and Liebner and continued to improve his knowledge of mathematics and optics. In 1814, he examined the dark lines in the solar spectrum, discovered earlier by Wallaston, in great detail for the purpose of measuring the homogeneity and optical constants of glass. From 1821, he researched into the manufacture and equations of transmission and reflecting diffraction gratings. Under Fraunhofer's guidance, the workshop designed and produced the finest possible optical and mechanical instruments which permitted others to develop spectroscopy for analytical purposes [153].

Friedlieb Ferdinand Runge (born 8 February 1794, Billwärder (now part of Hamburg); died 25 March 1867, Oranienburg) at the age of fifteen was apprenticed to an apothecary in Lübeck (see Fig. 2.19 for his portrait). He then studied medicine in Berlin, Göttingen and graduated for the Universität Jena in 1819 [154, 155]. His dissertation dealt with the physiological effects of belladonna. Runge was asked to demonstrate the dilation experiment on his cat for Goethe who was so impressed he gave him some rare coffee beans and suggested him to try to determine what compound in the beans gave them their physiological effect [156]. Runge accepted the challenge and within months isolated caffeine from them. Runge then returned to Berlin and received a doctorate in chemistry in 1822.

Fig. 2.19 Portrait of Friedlieb Ferdinand Runge (1794–1867)

Then, after 3 years travelling in Europe visiting chemical factories and laboratories became *Privatdozent* (Assistant Professor) at the Schlesische Friedrich-Wilhelms-Universität Breslau (now Wrocław/Poland) becoming Extraordinary Professor in 1828. Finding conditions were unfavourable to the development of his experimental researches moved to Berlin in 1831 and put an end to his academic career. In 1832, he took a position with a chemical works, *Chemische Produkten-Fabrik zu Oranienburg* (near Berlin). Given almost a free hand, in this industrial laboratory, Runge began the most fruitful period of his life carrying out his important study of analytical reagents, synthetic dyes and the discovery of coal–tar products [157]. The history of chromatography begins with the work of Runge when he observed that certain coloured substances when spotted onto a filter paper spread out into concentric rings [158, 159], and these he recorded in two books [160, 161]. He retired from the firm in 1852 but worked as a consultant until his death.

Heinrich Rose (born 6 August 1795, Berlin; died 27 January 1864, Berlin) was born into a family of scientists, his father and grandfather, both named Valentin Rose, were pharmacists who wrote on pharmaceutical and chemical topics [162, 163] (see Fig. 2.20 for his portrait). Rose first trained as a pharmacist in Danzig (now Gdańsk/Poland) but war against Napoleon intervened. He was in Paris with the occupying army in 1815, whilst there he met the leading French scientists including Berthollet. On his return to Berlin, he worked with Klaproth, long associated with the Rose family. He continued with his pharmaceutical apprenticeship in Mitau (now Jelgava/Latvia), near Riga. In 1819, he travelled via St. Petersburg and Finland to Stockholm to work with Berzelius on mica and then on the properties of titanium. Rose left Stockholm in 1821 and went to Kiel [24XII] and submitted his doctoral thesis on compounds of titanium and then returned to Berlin. In 1822, he became

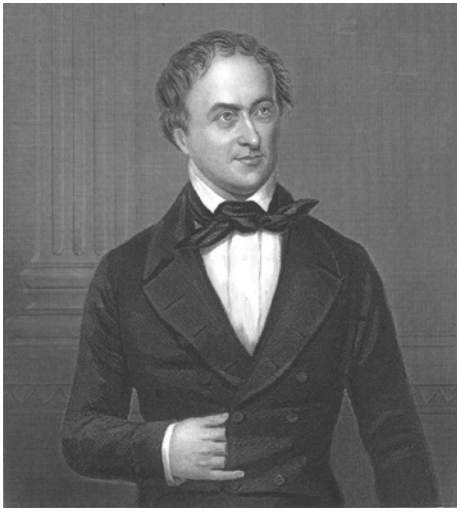

Fig. 2.20 Portrait of Heinrich Rose (1795–1864)

Privatdozent in chemistry at the Friedrich-Wilhelms-Universität Berlin, a year later *Extraordinarius* and in 1835, *Ordinarius*, i.e. as a full professor.

Rose's contributions to chemistry were twofold, firstly by the training, he gave directly at the Friedrich-Wilhelms-Universität Berlin and indirectly through his great textbook of analytical chemistry, *Handbuch der analytischen Chemie* [164–166]. His second contribution was by his vast number research papers, mainly on analyses of inorganic materials and minerals [167]. His textbook was first published in German in 1829 and in translation, English (1831); French (1832); Italian (1835–1838). The text is divided into two parts, qualitative and quantitative. In the qualitative section, Rose dealt with soluble as well as insoluble materials, reagents and the detailed behaviour of elements and their most important compounds. The quantitative section gave details of the determination of elements and necessary modifications required if other elements that can interfere were present. The calculations were carried out using the tables published by Berzelius. The text went through several editions and translations, being in their time, the standard reference works on the subject. Its importance can be judged from the translator's preface to the English edition:

> The high repute in which the Author of the following Work is held as an Analyst, renders it altogether unnecessary for me to offer any apology for the publication of this translation. As the English chemist possesses at present no competent literary instructor to guide him in his analytical researches, it may be assumed that a Work, emanating from the Berlin School, and sanctioned by the name of Rose, will not be looked upon with indifference.

The sixth and last German edition was prepared by Finkener after Rose's death [165].

Friedrich Wöhler [born 31 July 1800, Eschersheim (now part of Frankfurt/Main); died 23 September 1882, Göttingen] after early education in Frankfurt, he studied medicine at the Philipps-Universität Marburg [24XIII] and then at Heidelberg [24XIV] where he was graduated in 1823 [168–170] (see Fig. 2.21 for his portrait). At Heidelberg, Gmelin facilitated Wöhler's interest in chemistry and encouraged him to go abroad for further training and recommended him to Berzelius in Stockholm. Here, he received rigorous training in mineral analysis and formed a firm and long-lasting friendship with Berzelius. He was appointed in 1836 to the chair of chemistry in Göttingen to succeed Stromeyer. Wöhler is best known for his contributions to organic chemistry, starting with synthesis of urea from inorganic sources, and collaboration with Liebig. He met Liebig in 1825 over a minor squabble concerning the interpretation of analytical results of silver fulminate and silver cyanate, a classic example of isomerism. Wöhler's success in organic chemistry owed much to his analytical skills. In addition, he retained a lifelong interest in the analyses of minerals, and particularly of meteorites, and published extensively on these topics [171]. He also wrote three analytical texts, *Beispiele zur Übung in der analytischen Chemie* [172], *Praktische Übungen in der chemischen Analyse* [173] and *Die Mineral-Analyse in Beispielen* [174].

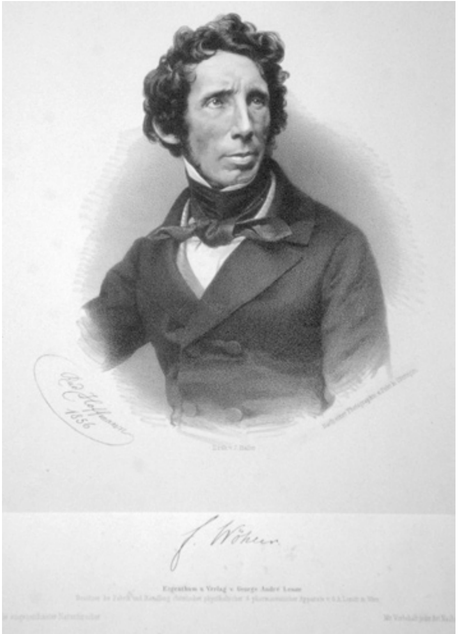

Fig. 2.21 Portrait of Friedrich Wöhler (1800–1882)

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