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Review

Analytical chemistry in Belgium: an historical overview

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Abstract. The people, places and political influences of importance in the history of chemistry in Belgium have been reviewed with particular reference to analytical chemistry.

Keywords: Review; history of analytical science; Belgium; analytical chemistry

Analytical chemistry has been and continues to be one of the most important and fundamental areas in the development of both classical and modern chemistry [1]. This is because the basic laws of definitive proportions and of multiple proportions could only be established after chemists determined, by elementary analysis, the composition of compounds.

Around 1500, chemical knowledge lagged behind that in other branches of science, because speculative alchemy, based on chemical technologies and philosophical theories, then held sway. In 1543, almost one hundred years after J. Gutenberg had devised the first practical printing press, two revolutionary books were published. The first, by Nicholas Copernicus (1473–1543) [2], held that "the centre of the earth is not the centre of the universe" [3]. The other was the book by the Flemish anatomist, Andreas Vesalius (1514–1564) [4], in which human anatomy was portrayed with an unprecedented accuracy [5]. These two books are important, being amongst those that mark the beginning of the Scientific Revolution: the Renaissance, when a new spirit appeared in medicine and the sciences. The origin of chemical analysis and hence of analytical chemistry in Belgium may be considered to have started with the work of the Flemish physician, Johannes Baptista Van Helmont (c. 1580–1644) [6–10]. Van Helmont was a follower of Theophrastus Philippus Aureolus Bombast Von Hohenheim (1493–1541) [11], commonly called Paracelsus, who had claimed that alchemy was not merely of use to discover techniques for transmutation of metals, but also to be used for the preparation of chemical based medicines with which to treat diseases (iatrochemistry).

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The early period up to the demise of the Phlogiston theory

Johannes Baptista Van Helmont was born in Brussels in 1577 or 1580 and died in 1644 either in Brussels or in Vilvoorde [6–10, 12] (for portrait see Fig. 1). He was descended from a noble and ancient Flemish family. He studied arts at the University of Louvain until 1594. After attending the Jesuit's school in Louvain, he finally turned to the study of medicine and obtained his medical degree in 1599. Van Helmont realized however the need in medicine for more than book

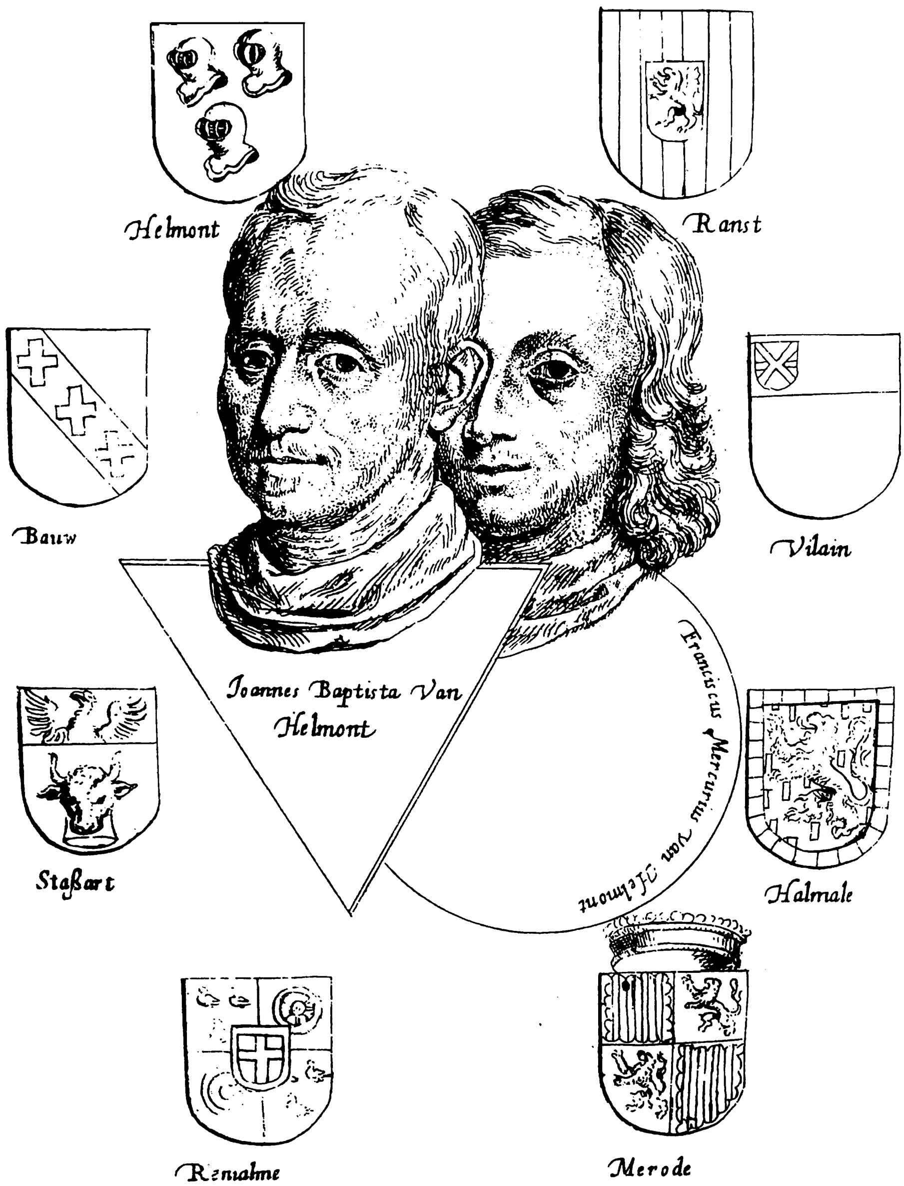
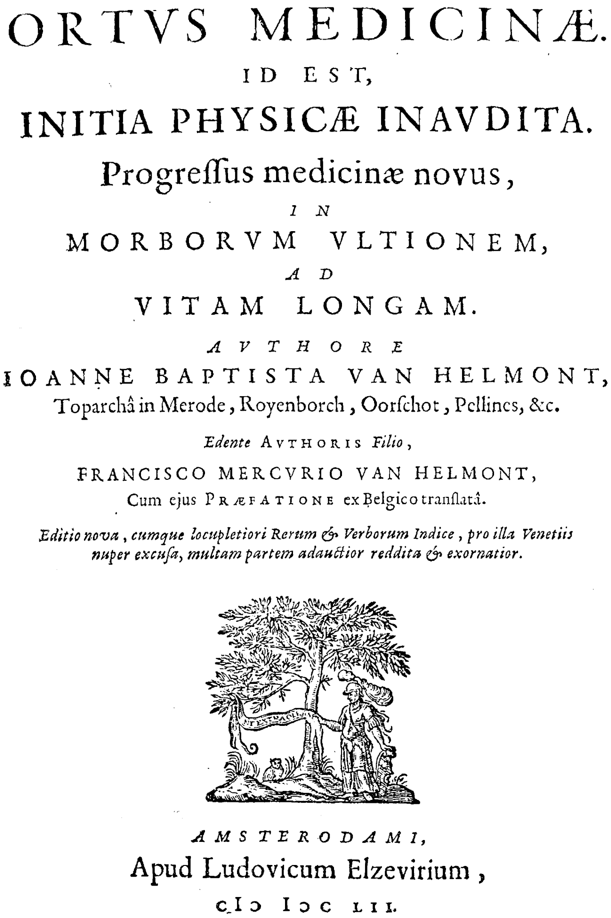


Fig. 1. Portrait of Johannes Baptista Van Helmont (c. 1580–1644) and his son Franciscus Mercurius Van Helmont (1614–1699), frontispiece of *Ortus medicinæ*... (1648) [17]

learning. He sought more knowledge through visits to Switzerland and Italy (1600–1602) and to France and England (1602–1605). In 1609 he married Marguerite van Ranst, also from the nobility. After this he embarked on private research for seven years (1609–1616) at Vilvoorde, near Brussels. The Van Helmont's had five daughters and one son.

Van Helmont lived in troubled times, because the Spanish occupation was trying ruthlessly to eradicate the rebellion against Catholicism. From 1625, Van Helmont was involved with ecclesiastic and inquisition authorities because of the interest he took in the controversy over the "weapon salve" and "the magnetic cure of wounds" [13–16]. After several interrogations in the 1630s he was released but placed under house arrest for most the rest of his life.

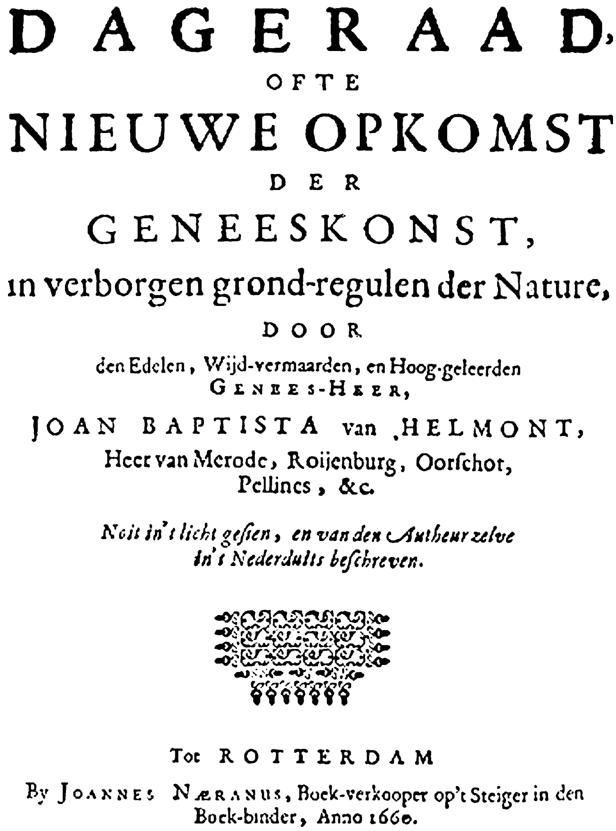
Shortly before his death he gave his son, *Franciscus Mercurius Van Helmont* (1614–1699), all his papers, charging him to publish them (for portrait see Fig. 1). These papers and the parts previously published separately, mostly in Flemish, were translated into Latin, edited and resulted in *Ortus medicinae*..., (1648) [17] (for title page of 1652 edition see Fig. 2) this was translated into English, published and republished, in full or in part, numerous times [10, 18]. Many of Van Helmont's treatise were published in the Flemish, *Dageraed* [19] (for title page, 1660 edition, see Fig. 3) but this was not a Flemish version of the Latin *Ortus*



ORTVS MEDICINÆ.
ID EST,
INITIA PHYSICÆ INAVDITA.
Progreſſus medicinæ novus,
IN
MORBORVM VLTIONEM,
AD
VITAM LONGAM.
AVTHORE
IOANNE BAPTISTA VAN HELMONT,
Toparchâ in Merode, Royenborch, Oorſchot, Pellines, &c.
Edente AVTHORIS *Filio*,
FRANCISCO MERCVRIO VAN HELMONT,
Cum ejus PRÆFATIONE ex Belgico tranſlatâ.
Editio nova, cumque locupletiori Rerum & Verborum Indice, pro illa Venetiis nuper excuſa, multam partem adauctior reddita & exornatior.

AMSTERODAMI,
Apud Ludovicum Elzevirium,
CIƆ IƆC LII.

Fig. 2. Title page of Van Helmont's *Ortus Medicinæ*... Editio nova (1652)



DAGERAAD,
OFTE
NIEUWE OPKOMST
DER
GENEESKONST,
in verborgen grond-regulen der Nature,
DOOR
den Edelen, Wijd-vermaarden, en Hoog-geleerden
GENEES-HEER,
JOAN BAPTISTA van HELMONT,
Heer van Merode, Roijenburg, Oorſchot, Pellines, &c.
Noit in't licht geſien, en van den Autheur zelve in't Nederduits beſchreven.

Tot ROTTERDAM
By JOANNES NÆRANUS, Boek-verkooper op't Steiger in den Boek-binder, Anno 1660.

Fig. 3. Title page of Van Helmont's *Dageraad*... (1660) [19]

[17]. It appears to have been written much earlier and compiled by J. B. Van Helmont and not by his son. The book is more concise than *Ortus*, and Van Helmont gives his motive for writing in the vernacular, "that the truth is more naked when offered in a simple style". Why the publication was delayed until 1659, 15 years after his death is not clear.

Herein, the focus is on some of Van Helmont's contributions to chemistry [9, 10]. Key items have been selected using Partington's, fully referenced (to page or to Van Helmont's numbered section of the page(s)), detailed analyses of the chemical content of *Ortus* medicinae (1652 edition) and *Dageraed* (1659 edition) [9]. Particular attention was paid to Van Helmont's views on the elements and his observations on gases, water, urinary calculi, fermentation and on inorganic chemicals and reactions. The chemical contributions are much clearer to follow than Van Helmont's discoveries in medicine and his medical views, which were embedded in his discourses on natural philosophy, cosmology and religious metaphysics, which are particularly difficult for modern readers to comprehend. For although Van Helmont contributed to the transition from alchemy to chemistry he claimed to have used a small piece of the philosopher's stone to convert mercury into gold and thus remained "a child of his time".

An important feature of the chemical work of Van Helmont was its quantitative character; he made extensive use of a balance. He clearly demonstrated the law of indestructibility of matter by dissolving metals in acids and recovering these metals by precipitation. The balance was also used in his famous "willow tree" experiment in which he planted a willow tree in a weighed amount of earth. After watering the tree faithfully, each day for five years, Van Helmont found that the tree had gained 164 pounds, whilst the weight of the soil had not changed. This proved to him that the tree represented water transformed into another substance.

In another aspect Van Helmont was unusually advanced. He was the first to recognize the philosophical implications that there is more than one "air like" substance. He observed that the vapours he obtained during chemical reactions were different substances from that of air. Because vapours, unlike liquids and solids, have no fixed volumes, but could fill every container, he considered these as, matter in complex chaos. The name ‘‘gas’’ was almost certainly derived by Van Helmont from the Greek word of ‘‘chaos’’ and used, as such, in his Flemish texts. His extensive study of gases has earned him the title of ‘‘father of pneumatic chemistry’’. He made the discovery of his first gas, carbon dioxide, which he called ‘‘gas sylvestre’’, because he obtained this gas by burning wood. He investigated and categorised a large number of gases (modern formulae in parenthesis), including:

– Gases evolved from Spa waters (CO_2).
– Gases produced by burning charcoal (CO and CO_2).
– Gases that form in cellars where wine is fermenting (CO_2).
– Poisonous red gas (NO_2) that is formed from aqua fortis (HNO_3) on silver.
– Gas evolved from aqua fortis (HNO_3) and salammoniac (NH_4Cl) in the cold (Cl_2).
– Sulphurous gas that ‘flies off’ from burning sulphur (SO_2).
– Intestinal gas which is flammable (H_2, CH_4, H_2S . . .).
– Gases evolved in putrefaction (H_2, CH_4, H_2S . . .).

Van Helmont noted also that gases can explode glass containers and some could be condensed into liquids. From the gases that Van Helmont produced it can be deduced that he was working in different technical fields. The gas formed when wine is fermenting and the intestinally produced gases (he called this ‘‘the wind’’, spelled in the same way in Flemish as in English) show Van Helmont’s interest in fermentation and in digestion.

He showed that the gas evolved from Spa water was the same as his already discovered ‘‘gas sylvestre’’. It is important to stress the fact that during the period of iatrochemistry, in the 16th and the 17th centuries, a great deal of work was carried out on the examination of mineral waters and on their medicinal effects. In Belgium, in the region of Liège a large number different mineral water springs with therapeutic effects are found, the most important are those situated in Spa and Tongeren [20].

The physicians of Ernest Ferdinand (1554–1612), Prince Bishop of Liège and Arch Bishop of Cologne

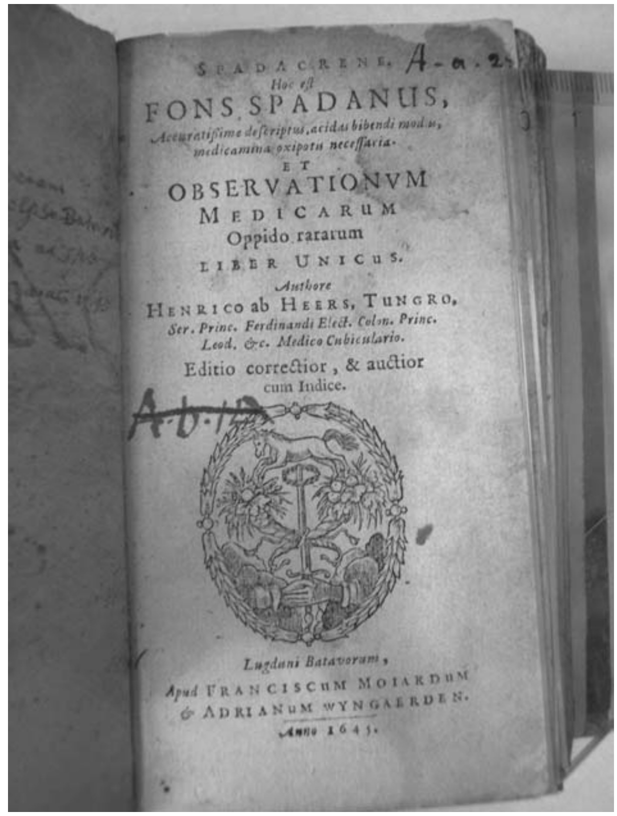

SPADACRENE.
Hoc est
FONS SPADANUS,
OBSERVATIONUM
MEDICARUM
Oppido rararum
LIBER UNICUS.
Authore
HENRICO ab HEERS, TUNGRO,
Editio correctior, & auctior
cum Indice.
Lugduni Batavorum,
Apud FRANCISCUM MOIARDUM
& ADRIANUM WYNGAERDEN.
Anno 1645.

Fig. 4. Title page of De Heer’s *Spadacrene* (1645) [25b]

were asked for chemical analysis in relation with the treatment of diseases with the waters of the springs. *P. Gheerincx* (1549–1604) first published in 1583 [21] on the composition of several Spa waters and further results in 1599 [22]. In 1614 his first cousin, physician *Henri De Heer* (1570–1636) [23] published *Spadacrene* (for title page see Fig. 4) about the different springs in Spa [24]. This volume was later re-published several times [25]. De Heer’s reported that the Spa waters contained different dissolved substances and that they could be used therapeutically to treat a number of diseases. Robert Boyle in *Usefulness of Natural Philosophy* [26] refers to the list of medical conditions curable with mineral waters given by ‘‘the famous and experienced *Henricus ab Heer* and to his *Spadacrene*’’. Van Helmont went to Spa and observed only a little iron vitriol and the gas ‘‘sylvestre’’ in the waters. In his 1624 publication, *Supplementum de Spadanis fontibus* [27], Van Helmont reduced the large number of useful therapeutical applications mentioned by de Heer. De Heer reacted with a virulent publication, *Vindiciae pro sua Spadacrene* [28] and attacked Van Helmont very severely.

This book of de Heer was published in different languages and the dispute between de Heer and Van Helmont became internationally well known. It is interesting to note that De Heer's name is in the 1624 list of censors during Van Helmont's appearances before the Inquisition for his being suspected of heresy.

Despite Van Helmont's writing in a very obscure style he was carefully studied and highly regarded by Robert Boyle (1627–1691) who cited him at least 222 times, including many long quotations and discussions of his work [29]. Van Helmont's work became very influential after his death, for example, H. Boerhaave (1668–1738) called him ''the greatest and most experienced of all chemists that have yet appeared . . . '' [30]. When reviewing the work of Van Helmont it is clear he made a major contribution to the foundations of classical analytical chemistry by his use of the balance and statements such as ''nothing is made of nothing'' and that he represents the start of the transition from alchemy to chemistry.

At the end of the Spanish occupation of the region now called Belgium, a new chair of chemistry was created in 1685 in the Faculty of Medicine of the old university of Louvain, however, none of the holders of this chair made any significant contributions in the field of analytical chemistry. The old university was closed in 1797 by the French occupation. During the Dutch period (from 1815 until the independence of Belgium in 1830), in 1816, Willem I created three state universities in the ''Southern Netherlands'', namely in Ghent, Leuven and Liège.

Fig. 5. Portrait of Jean Baptiste Van Mons (1765–1842)

The only chemist during this rather chaotic period with a clear international reputation was *Jean Baptiste Van Mons* (1765–1842) [31] (for portrait see Fig. 5). He was an excellent pharmacist and played an important role in the reform of pharmacy in Belgium and was officially appointed to work on the *Pharmacopoeia Belgica*, published in 1823 [32]. In addition to also being a productive chemist [31, 33] he is important for two further reasons. Firstly, Van Mons, was outside of France, one of the earliest supporters of Lavoisier's new oxygen theory. In 1789 he read a paper, to newly formed Society of Experimental Physics in Brussels, comparing the merits of Lavoisier's doctrine over the phlogistic view [34]. He was, the same year, invited by Lavoisier to collaborate with the editors of the *Annales de Chimie*. Later, in 1797, he joined the editorial board [35]. From 1790 he contributed to *Annales* translations of material from Brugnatelli's *Giornale fisico-medico*. In 1801 Van Mons began to publish his own journal in Brussels, *Journal de Chimie et de Physique* [36]. He played a very important role in disseminating the new theory of Lavoisier and took part in the debate about it that divided the German chemical community in 1792 [37]. He was very active as a central figure among European scientific correspondents being in contact with Bucholz, Fourcroy, Berthollet, Trommsdorff, Oersted and Volta amongst others. Van Mons produced a new and expanded edition of Fourcroy's *Philosophie Chimique* (1794) [38] and of Davy's *Élémens de Philosophie Chimique* (1813, 1816) [39]. The second indirect but major contribution to chemistry and to analytical chemistry in particular was that Van Mons had, after his appointment as professor chemistry at the State University in Leuven some excellent students, some of whom became his assistants. Among these were Laurent-Guillaume de Koninck (1809–1887), who became in 1836 professor chemistry at the University of Liège, Louis Melsens (1814–1886), who became in 1846 professor of chemistry in the Veterinary School in Kureghem and last, but not the least, Jean Servais Stas (1813–1891), whose work will be discussed in the next section.

In addition to his chemical reputation van Mons was a distinguished contributor to agricultural botany by his breeding of new varieties of *pyrus communis* (pears) [40]. He was responsible for the development of 40 named varieties, many of which are illustrated in the United States Department of Agriculture, Pomological Watercolour Collection [41]. At one time 80,000 seedlings were growing in his gardens. His observations are regarded as still valid and useful today to those wishing to select seeds for propagation or cultivars for further study [42].

The Nineteenth Century

Jean Servais Stas

Jean Servais Stas (1813–1891) was born at Leuven in 1813 [43–50] (for portrait see Fig. 6). In 1832 he started his studies in the Faculty of Medicine at the State University in his native city. Because of his great interest in chemistry he was engaged, in 1834, as assistant of Van Mons. In 1835 he obtained his medical degree, the same year that the Belgian government decided to keep only two of the three state universities namely those in Ghent and Liège. The year before, 1834, two free universities were created in Belgium, a Catholic one in Mechelen and a liberal one in Brussels. After the abolition of the State University in Louvain, the Catholic University moved from Mechelen to Louvain. Stas did not practice medicine but chemistry. His first research, made in association with his friend L. G. de Koninck, was into the properties of a crystallisable glucoside, they named phloridzine, extracted from the bark of the roots of apple trees from the orchards of Van Mons. Stas was appointed to assist the new professor of chemistry in Louvain, M. Martens (1797–1863). However, because of Stas's liberal ideas he could no longer stay at the Catholic University, encouraged by Van Mons, he went to Paris in 1837. In Paris he worked in the laboratory of J. B. A. Dumas (1800–1884) at the Polytechnic School. At first he continued work on samples of phloridzine brought with him, then on chemical types [50, 51]. Dumas, impressed by the exceptional promise of Stas, made him an associate in his researches, in particular, in the task of determining the atomic weight of carbon.

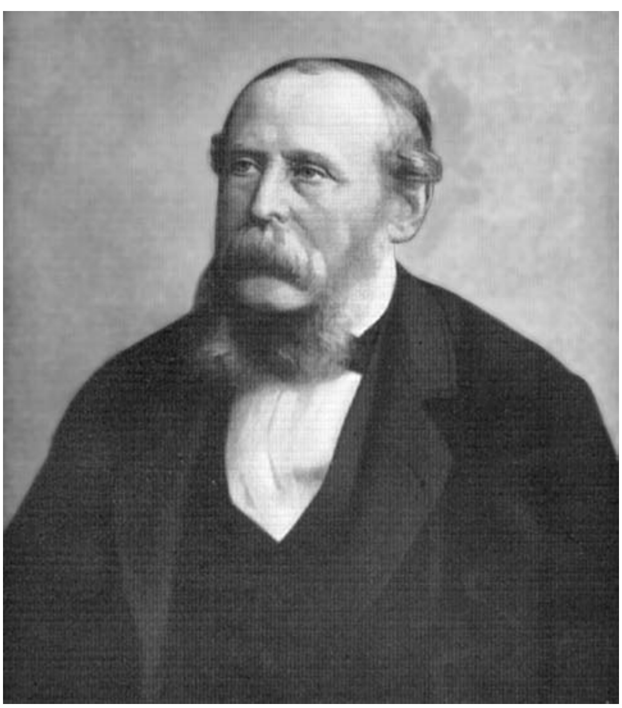


Fig. 6. Portrait of Jean Servais Stas (1813–1891)

Since the discovery of naphthalene in coal tar, in 1816, problems had arisen in the analyses, by combustion, of hydrocarbons that were rich in carbon. Dumas became convinced that the problem was due to errors in the values used for the relative weights of the elements. Dumas and Stas, in a study that is still a model for today, burned carbon (diamond, purified and artificial graphite) in pure oxygen and from the weight of carbon (adjusted for any residual ash) and of carbon dioxide (absorbed in alkali) they found the atomic weight of carbon to be 12.000 ± 0.002 (if $O = 16$) or 75.005 (if $O = 100$) [52].

In 1841, Stas returned to Brussels as Professor of Chemistry in the Military Academy. He taught at this establishment until 1865 when throat trouble, that affected his speech, forced him to resign his chair. Stas then became a Commissioner of the Mint, but resigned in 1872. Because there was no laboratory at the Military Academy, Stas made a private laboratory in his house in a suburb of Brussels. During his professorship at the Military Academy, he carried out his famous determinations of atomic weights. Stas never married. His patrimony and a considerable part of his salary went to fund the expense of his researches. In 1860 he wrote to his father ‘‘To achieve my works, I have made sacrifices that have brought me not far from poverty’’ [48a].

The atomic theory played an important role in the understanding and in the practice of chemistry throughout the 19th Century. The first recorded table of atomic weights was that by J. Dalton (1766–1844) in his diary entry 6th September 1803. On October 21th, the same year, he read a paper to the Manchester Philosophical Society, "On the absorption of Gases by Water and Other Liquids", which was published in 1805 and contains his table of the relative weights of the ultimate particles of gaseous and other bodies [53]. J. J. Berzelius (1779–1848) then undertook an extensive analytical program aimed to produce an atomic weight table with more exact values, producing his first table in 1814 [54]. One problem at the time was the selection of an element as the standard for purposes of comparisons. Dalton had used 1 for hydrogen, but because oxygen is more often present in chemical compounds, Berzelius proposed oxygen as the standard, assigning it a relative atomic weight value of 100.

As early as 1815, an English physician, W. Prout (1786–1850) had advanced the idea that all atomic weights were whole numbers if the atomic weight of hydrogen was taken as unity [55, 56] (see Fig. 7 for title page of the Alembic Club reprint of the key Prout, Stas and Marignac papers). The value for the atomic weight of carbon, determined by Dumas and Stas, provided an experimental support in favour of Prout's hypothesis. From the point of view of the philosophy of nature this result was immensely important, because it confirmed the 'theory of the unity of matter'. Because of his further results, given in revised tables of 1818 and 1826, Berzelius could not accept Prout's hypothesis [57]. In his private laboratory Stas restarted work on the atomic weight of carbon and from 1842 till 1845 worked, not using the combustion of diamonds, but that of carbon monoxide, into carbon dioxide. He found values between 75.00 and 75.06 ($O = 100$) [58]. Because Stas did not like to make speculations and believed only the results of experimental work, he began to have doubts about the exactness of Prout's hypothesis. Hence Stas then started to determine the atomic weights of elements that values seemed to confirm the hypothesis of Prout. He worked on chlorine, bromine, sulphur, nitrogen, potassium, sodium, lithium, lead and silver. He paid special attention to the purification of the materials and used large weights of substances, believing that this led to greater accuracy.

In the course of long and laborious work, he obtained some results in excellent agreement with Prout's hypothesis and others that were completely irreconcilable with this hypothesis. He published his results in 1860, concluding that Prout's hypothesis was nothing more than an illusion [59]. J. B. Dumas wrote to Stas that the results could be the object of a lot of discussions [60]. J. De Marignac (1817–1894) of Geneva, old student of Dumas, tried to rescue Prout's hypothesis by throwing doubt on the constancy of the law of combining proportions [56, 61]. To refute this objection Stas resumed his determinations and in 1865 presented data for the rigorous demonstration of the invariability of the relative atomic weights of elements in different compounds [62].

In 1878 Dumas found that pure silver fused and solidified in contact with air, absorbed a small quantity of oxygen [63]. This observation endangered the

Alembic Club Reprints—No. 20

PROUT'S HYPOTHESIS

PAPERS BY

WILLIAM PROUT, M.D.
(1815-16)

J. S. STAS
(1860)

AND C. MARIGNAC
(1860)

Edinburgh:
PUBLISHED BY THE ALEMBIC CLUB

Edinburgh Agents:
OLIVER AND BOYD, TWEEDDALE COURT

London Agents:
GURNEY AND JACKSON, 33 PATERNOSTER ROW

1932

Fig. 7. Title page of Alembic Club Reprints-No. 20 [56]

Table 1. Stas' 1860, 1865 and 1876–1881 values for atomic weights and those of I.U.P.A.C. in 1961

Élément	I	II			III (1961)
		1860	1865	1876–1881	
Chlore	35,5	35,46	35,457	–	35,454
Soufre	32,0	32,0742	–	–	32,065
Azote	14,0	14,041	14,044	14,0550	14,0072
Argent	108,0	107,943	107,930	107,9300	107,874
Potassium	39,0	39,13	39,137	39,1425	39,104
Sodium	23,0	23,05	23,049	23,0455	22,9906
Plomb	207,0	206,914	–	–	207,20
Brome	80,0	–	79,952	–	79,912
Iode	127,0	–	79,952	–	126,9092
Lithium	7,0	–	7,022	–	6,939

whole of Stas' work, because silver was the intermediary in his determinations of atomic weights for quite a few elements. Stas was sixty-five years old, but he could show that the possible error in the atomic weight of silver was so small that it was without effect on his other results [64]. The exact values of atomic weights were of utmost importance for the establishment of the periodic system in 1869 by D. I. Mendeléeff (1834–1907) [65].

In 1889 during visit of L. Baekeland (1863–1944), Stas told him ''I had to admit that I was beaten and had spent a most important part of my life in killing my first love (Prout's hypothesis) as a theory'' [66]. In Table 1 are the final values of the atomic weights as determined by Stas compared with the accepted I.U.P.A.C. values in 1961 [48]. The value given for iodine in this table is a typographical error, the correct value is 126.850.

The twelve atomic weights established by Stas in 1860 were considered the ultimate in accuracy for the next four decades. He was awarded the Davy Medal of the Royal Society in 1885 for his contributions to the determination of atomic weights. In 1904 T. W. Richards (1868–1929) began to repeat Stas's experiments and made some small corrections based on his knowledge of the physical chemistry of sparingly soluble salts. He was awarded the Nobel Prize in 1914 for a lifetime's work on the determination of high accuracy atomic weights, the first American chemist to be so honoured [67, 68].

Stas represented Belgium on the International Committee of Weights and Measures [46] and took an active part in the investigation of the properties of the metals of the platinum group, and work relating to the production of iridium-platinum ingots to be used for the production of the new international standards of weights and measures. He was member of many different scientific committees and organisations in Belgium such as the Commission on Hygiene, the Committee of the Royal Library and the Belgian Academy of Sciences [46].

Stas's important contributions to emission spectroscopy, published posthumously by W. Crookes (1832–1909) in Chemical News in 1895 and 1896 [50c] were overlooked by J. R. Partington (1886–1965) in his monumental four volume *History of Chemistry* [44] and thus, are almost unknown these days. These studies were made in response to a paper by J. N. Lockyer (1836–1920) who in 1878 reported that several elements were compounds capable of dissociation by heat [69]. Such a theory could not fail but to interest Stas, and he set out to see if the same observations would be seen with bodies as purified as he had learnt to produce. It is said it took eleven years to prepare substances he could call pure. He prepared ultra pure compounds of silver, sodium, potassium, lithium, calcium, strontium, barium and thallium. He found at the highest temperatures at which he worked, even at the melting point of iridium, the lines of these elements remained the same and that these elements were not dissociated. This work [50c, 70, 71] that cost so much labour, has been described as ''the crowning work of Stas'' [46].

In the public arena, Stas was a recognized authority on medico-legal matters. One murder trial in which he took a leading part had a lasting influence in toxicology. In the 1850 murder by Count Hyppolyte Visart de Bocarmé of his brother-in-law, nicotine poisoning was suspected as cause of death. But at that time no one had managed to detect vegetable poisons in human tissues, indeed four years earlier, M. J. B. Orfila (1787–1853), the leading European toxicologist, had declared it may never be possible [72]. Stas, as government expert, after three months work devised the still-used ''Stas-method'' of extracting vegetable alkaloids from body fluids and tissues, prior to their identification in the pure state [73].

The emergence of formal courses in analytical chemistry

The teaching of the sciences, including that of chemistry, at the Belgian Universities in the 19th Century was greatly affected by events at the national level [74]. As noted earlier, in 1835 there was in Belgium two State Universities and two Free Universities, one Catholic one the other, Liberal. In 1836 the government attached to each State University a Special School for the training of engineers. In 1837 a non-university High School for mining engineers was established at Mons [75].

In the Faculty of Sciences, students could choose between an orientation towards mathematical and physical sciences or towards natural sciences. During the first year (for the diploma candidates) a course was organised on ‘‘inorganic and organic chemistry’’. Students being trained in the Faculty of Medicine as future physicians also followed this course. Because there were not many career possibilities for graduates in sciences, most of the students following the chemistry course were intending physicians. In the Special School for Engineers a course on applied chemistry was given.

The development of chemistry teaching, like for the other sciences was severely hampered by the rivalry between the State and the Free Universities, especially on the numbers of students and the conferring the academic degrees. There existed distrust in the equivalence of the degrees and diplomas. The government solved this difficulty by the creation of central juries to examine all students for a given subject. This situation had dramatic effects, by degrading the level and quality of chemical knowledge of the students graduating in chemistry. Courses focussed on the passing of the examinations rather than broad appreciation of the subject.

At the time, no space was devoted in the curriculum for chemical laboratory training, this was only compulsory for the training of the engineers. However the arrival of A. Kekulé (1829–1896) in Ghent in 1858 created a new situation. Kekulé’s request for a proper laboratory was, at that time, unusual in Belgian science. Thanks to the influence of J. S. Stas, the government created, in 1862, a well-equipped laboratory, where research facilities existed and a free course in chemical experimentation was offered to the few undergraduate students in the last year of their doctorates. The Professors of chemistry in Liège then asked for the creation of a similar laboratory to that which had been provided in Ghent, but the government refused. Laurent-Guillaume De Koninck, Professor Chemistry, stopped doing chemical research and turned towards palaeontology. In 1869, Louis Henry (1843–1913), Professor Chemistry in Louvain, insisted on the need for a laboratory for students. However, most of the teaching and research laboratories were built after 1880 [75].

In 1876 the government abolished the system of the central juries; each university became free to examine students for their own degrees and diplomas. The year 1876 was a crucial year in the history of analytical chemistry in Belgium, because in this year the government required two new courses to be given during the training of pharmacists, created originally in 1849 in the Faculty of Medicine, namely a course on analytical chemistry and one on toxicology. Earlier, aspects of chemical analysis were studied by students of pharmacy but not as a specific course. The course on analytical chemistry also became an optional one for students in the last year of study in the Faculty of Science and for the training of engineers a short course on analytical chemistry was included within that on industrial chemistry. The course of analytical chemistry for the training for pharmacists was obligatory and in addition to lectures included practical classes. The first Professors in Analytical Chemistry in Belgium were Ch. Blas (1839–1919) in Louvain, L. L. De Koninck (1844–1921) in Liège, E. Dubois (1842–1892) in Ghent and A. Joly (1841–1911) in Brussels.

In 1890 there was a very important reform in the curricula. The doctorate degree in natural sciences was split up in four groups, zoology, botany, earth sciences and chemistry. The most important innovation was that a degree of doctor could only be obtained after carrying out an original scientific research, written up in a thesis and defended in public. By the introduction of research as a prerequisite for graduation, a new era for chemistry commenced.

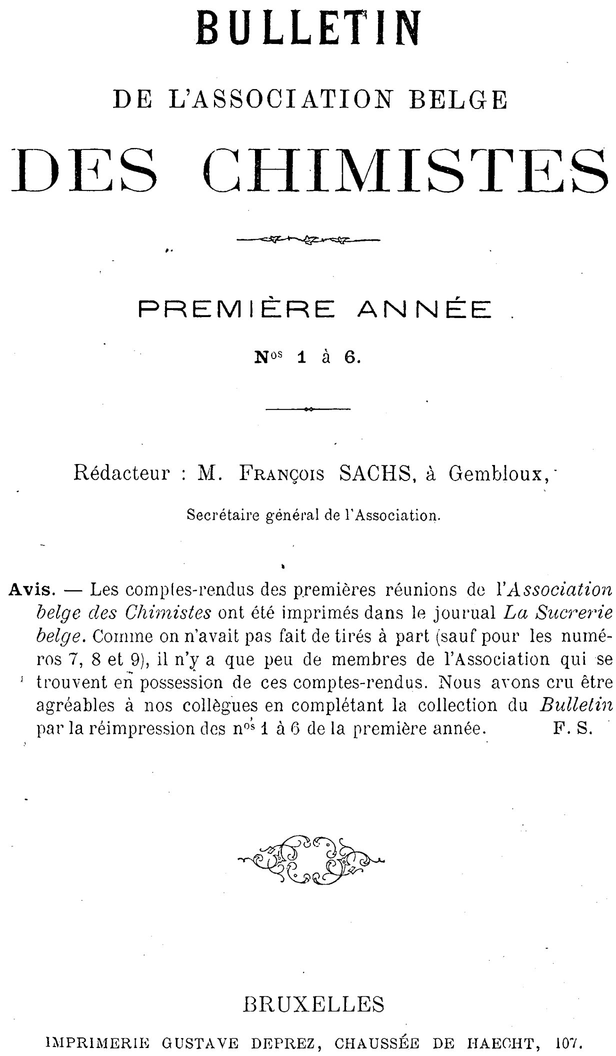
The agriculturalists were the third group of specialists, beside the pharmacists and engineers, who were strongly reliant on chemistry. In 1860 a State High School for Agronomics was established in Gembloux. Chemistry was taught from the beginning by one Professor, P. De Wilde (1835–1916). In the meantime the European agriculture crisis after 1875 when American cereals came onto the European market was important in Belgium and led the Catholic University at Louvain to open an Agronomic Institute, annexed to the Faculty of Sciences in 1878. The first Professor of Analytical Chemistry was A. Theunis (1848–1920). At the end of the 19th Century different specialised high schools were established, for the brewing, textile and chemical based industries such as metallurgy and sugar.

The professionalisation of analytical chemistry in Belgium

Whereas in most Belgian industries in the late 19th Century there were a few chemists, in the sugar industry their role was crucial and well recognised. The Belgian sugar industry was a rapid expanding sector in the 1880s. The crucial importance of the determination of the sugar content of the beet secured a prominent place for analytical chemists in the factories, in commercial associations and, last but not least, they were held in high regard by the farmers being defended by chemists of the government.

However, the methods used at the time for the determination of sugar were very controversial. The chemists working for the sugar factories and in the commercial associations were encouraged to find a consensus of opinion as to the best method for the analysis of sugar beet for trade purposes. The chemists decided that the best and most definitive way to solve this problem was to discuss the problem thoroughly and openly among all the "chemists" concerned. The first meeting to discuss new procedures for the analysis of sugar beet was held in Brussels on April 14th 1887 [76]. The 24 chemists present at this meeting thought it was of general interest to attract all chemists working in the Belgian industry; they went on to found the *Association Belge des Chimistes*, the Belgian Association of Chemists.

The founding members, mostly sugar chemists, created a sugar section. In 1889 two new sections were established. Because the government intended to promulgate a law on the falsification of foods, a section was formed concerned on food control and public hygiene [77, 78]. The members were mainly pharmacists, including all the relevant Professors and their associates in the four Universities. The next section brought together all chemists interested in agricultural problems, e.g. the analytical methods for artificial fertilisers. This section attracted mostly the agronomists. In 1890 a fourth section was created for chemists interested in the fermentation industries (beer, vinegar, etc. . . .). The last section was founded in 1896, especially for those interested in the chemical industry. It is interesting to note that the minimum number of ten chemists was never found when the board of the Association was asked to create a section on pure chemistry. Hence, up to the end of the 19th Century, the Association was mainly composed of


BULLETIN

DE L'ASSOCIATION BELGE

DES CHIMISTES

PREMIÈRE ANNÉE

Nos 1 à 6.

Rédacteur : M. FRANÇOIS SACHS, à Gembloux,

Secrétaire général de l'Association.

Avis. — Les comptes-rendus des premières réunions de l'*Association belge des Chimistes* ont été imprimés dans le journal *La Sucrerie belge*. Comme on n'avait pas fait de tirés à part (sauf pour les numéros 7, 8 et 9), il n'y a que peu de membres de l'Association qui se trouvent en possession de ces comptes-rendus. Nous avons cru être agréables à nos collègues en complétant la collection du *Bulletin* par la réimpression des nos 1 à 6 de la première année. F. S.

BRUXELLES

IMPRIMERIE GUSTAVE DEPREZ, CHAUSSÉE DE HAECHT, 107.

Fig. 8. Title page of first volume of *Bulletin de l'Association Belge des Chimistes* (1887)

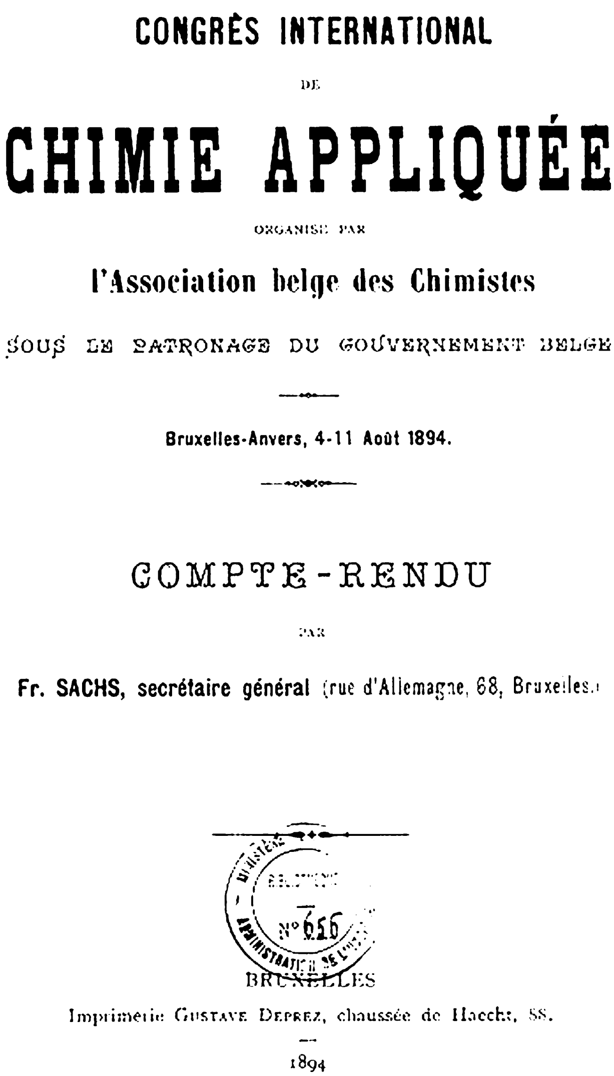
applied analytical chemists. The Association however had among its members a high number of Chemistry Professors of the four Universities and in the different High Schools.

From the start, the Association had its own autonomous journal, *Bulletin de l'Association Belge des Chimistes* (see Fig. 8 for the title page of the first volume of the *Bulletin*). This Bulletin was the main link between the members, the maximum number being 507 in 1901. Over the years the *Bulletin* became more and more like a scientific journal with original research contributions from their members.

The Association contained working chemist members (at the beginning it also included some directors of sugar industries), foreign members and members of honour. It is not surprising that shortly after the start

J. B. Stas became the first member of honour, because as was said at the time of the award, ‘‘We are all subordinate to Stas; he is for us the embodiment of the ultimate accuracy of the procedures in the analytical research’’ [79].

A very amazing achievement of the young Association was the organisation of the first International Congress on Applied Chemistry in 1894 in Brussels/Antwerp [80] (see Fig. 9 for the title page of the Proceedings). This gathering of 397 chemists from 27 different countries was the first of a long sequel of biennial congresses. The consecutive congresses were held in Paris (1896), Vienna (1898), Paris (1900), Berlin (1903), Rome (1906), London (1909) and Washington (1912). IUPAC lists these as the first conferences of their predecessor bodies [81]. The common theme through all these congresses was the harmonisation of analytical procedures for all kind of problems. During the series of these conferences, permanent commissions were established. At the fourth conference, Paris (1900), a commission was specially set up for analytical matters under the presidency of Professor G. Lunge (1839–1923) of Zürich, and contained at least two experts of each major country. At the fifth conference held in Berlin in 1903, a committee was nominated to harmonize the table of atomic weights [82].


CONGRÈS INTERNATIONAL

DE

CHIMIE APPLIQUÉE

ORGANISÉ PAR

l'Association belge des Chimistes

SOUS LE PATRONAGE DU GOUVERNEMENT BELGE

Bruxelles-Anvers, 4-11 Août 1894.

COMPTE-RENDU

PAR

Fr. SACHS, secrétaire général (rue d'Allemagne, 68, Bruxelles.)

BRUXELLES

Imprimerie Gustave Deprez, chaussée de Haecht, 88.

1894

Fig. 9. Title page of the Hand book for the First International Congress on Applied Chemistry, 1894

In 1898 the Association of Belgian Chemists was reorganised into local sections and abandoned the problem-orientated structure that had shaped the Association from its early beginnings [83, 84]. The eight local sections were mostly organised in localities with at least either a University or a high level technical school (as at Mons, Liège, Louvain, Brussels, Ghent and Gembloux), except for those based on Antwerp and Charleroi. The discussion themes in these meetings included a much wider variety of topics than before. In 1904 the name of the Association was changed to that of the *Société chimique de Belgique*, the Belgian Chemical Society, as this name was considered to reflect its more scientific composition [85].

It is clear that at the end of the 19th Century applied chemistry had more impact and deserved more attention by the chemists and also by the general public, than pure chemistry. After the turn of the Century, pure chemical research was possible at all the Belgian universities and the results filtered slowly through the Society. In 1905, after a common national conference in Liège held by the chemists of the Society and the pharmacists of their professional Association, Professors of Pure Chemistry, L. Henry (1843–1913) of Louvain and W. Spring (1849–1911) of Liège, were made members of honour of the new Society.

Some eminent practicing analytical chemists, past presidents of the Association of Belgian Chemists

The Association of Belgian Chemists was from the beginning led by Professors, besides colleagues with a high activity in the Association. The first series of Presidents of the Association were Ed. Hanuise (1887–1895), J. B. Depaire (1894–1896), A. Herlant (1897–1898), L. L. De Koninck (1899–1900), L. Crismer (1901–1902) and A. J. J. Van de Velde (1903–1904).

Edouard Hanuise (1842–1913), studied at the mining High School in Mons and qualified as a chemical engineer in 1864 and was appointed Professor in Geology and Mineralogy at Mons in 1867. He was from 1882 till 1908 member of the joint commission for arbitrage between sugar manufacturers and commercial associations. He took an active part at the creation of the Association of Chemists and became the first President [86]. His research interests were in the analysis of phosphates as fertilizers and on the problem of pollution by wastewater from sugar factories.

Jean Baptiste Depaire (1824–1910), qualified as a pharmacist in 1845, and from 1848 was active in legal-toxicological research [87]. He was Professor of Toxicology at the University of Brussels (1864–1900), but was involved in many administrative functions, for example, reorganisation of the School of Pharmacy in 1880, Rector of the University (1886–1888), etc... From 1854 till 1904 he was member of the Brussels town council. He became member of the Royal Medical Academy in 1862. His research interest focussed on general health aspects, poisons, toxic metals, and food adulteration. In the Association he became, in 1889, the first chairman of the section on food control and public hygiene [77]. In 1895 he became the second President of the Association at a very difficult moment when the "founding fathers", the sugar chemists, left the Association to found their own society, because their interests were not only in chemical problems but also in the technical aspects of the sugar production, which had been left outside the scope of the Association.

Achille Herlant (1850–1927), pharmacist, Professor of the detection of food falsification and adulteration, was the third President. A. Herlant specialised in applied analytical research in the adulteration of foods [88] and of natural products used medicinally [89].

Lucien Louis De Koninck (1844–1921) was the fourth President. His research and importance in the history of analytical chemistry will be discussed in the last section. He played an important role in the evolution of the Association from a community of applied chemists to one being inclusive of pure chemists [85].

Léon Crismer (1858–1944) graduated in pharmacy from the University of Liège in 1879 [90] (for portrait medal see Fig. 10). After a stay of three years at German universities, he became an assistant of Professor L. L. De Koninck. In 1893 he was appointed as Professor for General Chemistry at the Military Academy, Brussels. He became member of the Association in 1890. Crismer was a pioneer of the application of physical chemistry for the devising new analytical methods. His best known research is the study of the critical temperature of dissolution of two liquids which at normal temperatures are not miscible. He showed that the value of this critical temperature does require taking an exact weight or volume neither of the compound to be dissolved nor of the solvent itself. The critical dissolution temperature was found to be characteristic of the compounds being dissolved and was useful to confirm the purity of fats and vegetable oils. In 1896 he demonstrated to the food section of the Association that this method was quick, sensitive and accurate for the determination of the falsification or the adulteration of butter [91]. The Crismer Test is still used as an official method to characterise animal and vegetable fats and oils [92]. When he retired at 69 from the Military Academy the occasion was honoured by the Belgian Chemical Society and a portrait medal presented (for portrait medal see Fig. 9) [93, 94].

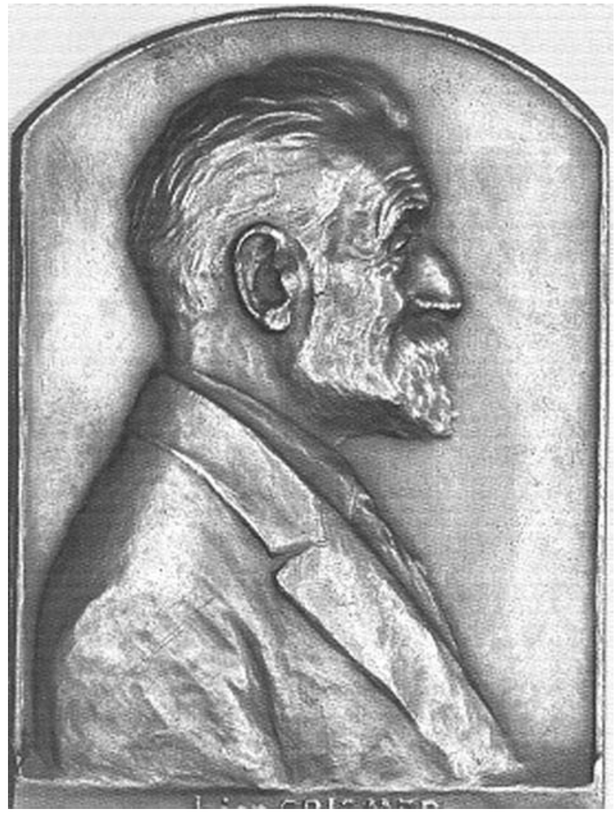


Fig. 10. Portrait Medal of Léon Crismer (1858–1944) [94]

Albert Jacques Joseph Van de Velde (1871–1956), the sixth President, studied at the University of Ghent

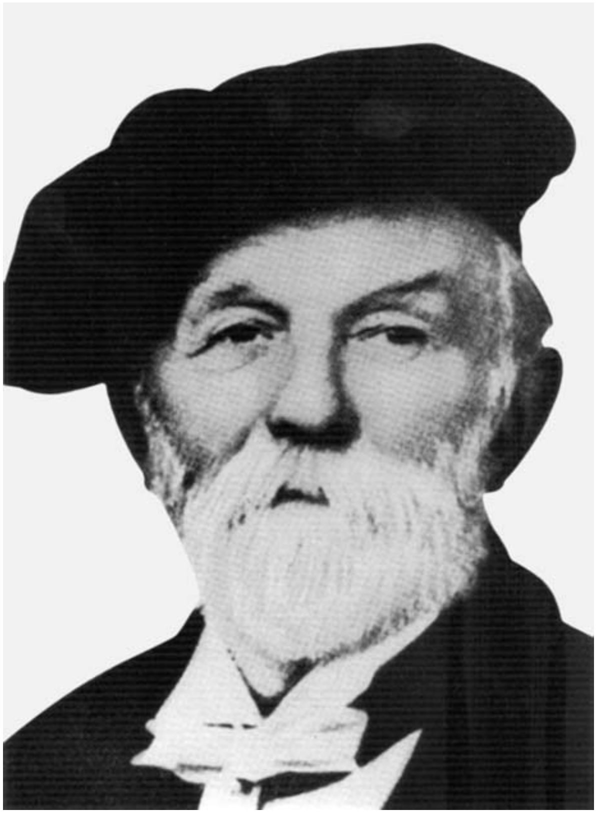


Fig. 11. Portrait of Albert Jacques Joseph Van de Velde (1871–1956)

and graduated doctor in natural sciences in 1893 [95] (for portrait see Fig. 11). He became an assistant of Théodore Swarts (1839–1911). Besides chemistry, Van de Velde was actively interested in a variety of different scientific disciplines, biology, biochemistry, bacteriology and last but not the least, in the history of science. In 1900 he became director of the laboratory on chemical control of the city of Ghent. Here he developed a service for the analysis of water and foods such as milk, butter, and bread, especially their falsification or adulteration and their bacteriological aspects. He was appointed as Professor General Chemistry in 1920 at the newly created Flemish State High School for Agronomics in Ghent and in 1925 he was appointed Professor of Food Sciences at the University of Ghent. His list of more than 600 publications shows his immense energy and his extraordinary knowledge in a wide range of different scientific disciplines. He was editor in chief of the Belgian Chemical Society Bulletin from 1907 till 1923.

Besides the Presidents of the Association a lot Professors of the Universities and the High Schools played an important roles, especially in the section of food chemistry, for example, Prof. Gustave Bruylants (1850–1925) of Louvain, Prof. Alphonse Van Engelen (1861–1921) of Brussels, Prof. Armand Jorissen (1853–1920) of Liège and Prof. Auguste Theunis (1848–1920) of Louvain High School of Agronomics.

The rise of academic analytical chemistry in Belgium

In this section, the evolution of academic analytical chemistry as a distinct discipline in Belgium will, for the first time [96], be outlined for the period 1876–1965. The year 1965 was chosen as the termination date because after that date a series of new Universities were created and their traditions are not, as yet, fully documented.

To be able to follow the development of chemical research in Belgium it is necessary to understand how the degree structure and the Universities have evolved over time. From 1835 the patterns of studies in the sciences, medicine and engineering were as follows, on admission to the University students studied for two years in the Faculty of Sciences to obtain the degree of "Candidate", this was equivalent to an "ordinary degree" in the British system. Success at this level could be followed by a further two years in the Faculty of Sciences to obtain a Ph.D., doctorate, in either mathematical and physical sciences or in natural sciences. To obtain the degree to practise medicine, Doctor in Medicine, a further three years study in the Faculty of Medicine were required after the candidate degree. Intending engineers continued their studies in the Special ("High") School of Engineering. From 1849, the qualification route for pharmacists after the candidate degree was two years work in an official pharmacy and one year of specific courses in the Faculty of Medicine. From 1876 the Faculties took over examining duties from the national central juries and awarded the degrees, instruction via lectures was strengthened by the introduction of compulsory practical classes with teaching assistants attached to some the Chairs. In 1890 the regulations for award of the doctoral degree in science introduced the requirement of a thesis describing original research and that pharmacists had to spend two years on specific courses in the Faculty of Medicine. The natural sciences were orientated to zoology, botany, earth sciences and chemistry. In 1929 the current sequence of degrees was established, two years study for the "Candidate Degree" (pass degree), a further two years study for the ‘‘Licentiate Degree’’ (extended honours or master’s degree). The ‘‘Doctoral Degree’’, (Ph.D.), normally requires an additional three years of study and original research.

From 1835 the four Belgian Universities taught in the French language despite Ghent and Louvain being situated in the Flemish speaking part of Belgium and Brussels being in a bilingual region. The introduction of a Flemish regime took place in Ghent over the period 1923–1930. At Louvain, in the decade from 1920 all the facilities were split in two regimes, one French the other Flemish, both retained their Catholic ethos. In 1969 the French speaking part of the Catholic University of Louvain moved to the French speaking area of Louvain-la-Neuve and a new Free University with a Flemish speaking regime was established in Brussels. The Free Universities (Civic Universities in the British terminology) were not founded or originally subsidised by the Government. After the First World War all four Universities had financial problems due to the needs for more teaching staff, new High Schools for training engineers, agronomists etc. and for provision of modern research space, it was only from 1930 that the Government paid the staff salaries in the Free Universities. In 1920, the Commission for Relief in Belgium (CRB), which had organised the countries provisioning during the First World War, donated the remaining funds to the four Universities and to the ‘‘University Foundation’’ whose aim was the expansion of higher education. The ‘‘National Fund for Scientific Research’’, created in 1928, provided the impetus for the revival of fundamental research in Belgium. CRB Fellowships were a further help as they allowed some of the best students to travel abroad for research experience in, for example, one of the larger American Universities.

It is generally accepted that analytical chemistry became a specialised area of chemistry in the Universities in the middle of the 19th Century [97–101]. At first the emphasis, in Belgium as in the rest of Europe, was on the development or refinement of the classical methods of gravimetric and volumetric analysis. After the First World War more and more attention was given to electrochemical and optical instrumental methods [102]. The history of fundamental analytical chemistry can be followed via the development of individual techniques or, as herein, based around the personalities and locations of those engaged in the teaching and research of the subject. The personalities of those teaching applied analytical chemistry in courses such as those of food chemistry, toxicology, medicinal chemistry and physiological chemistry have not, on grounds of space, been included in this account. The significant contributions of the various Belgian Schools of Analytical Chemistry have not, to date, been systematically recorded and indeed were overlooked by Brooks and Smythe in their review, ‘‘The Progress of Analytical Chemistry, 1910–1970’’ [103]. However, according to Boig and Howerton’s 1952 survey, Belgium was 11th in 1959, 16th in 1948, 15th in 1947 and 8th in 1927, 1907 and 1897 in the rankings by country for numbers of abstracts of papers in analytical chemistry [104]. The contributions, in both the classical and modern periods of analytical chemistry, by the Universities of Louvain, Brussels, Liège and Ghent will now be outlined.

The University of Louvain

(i) Period of Classical Analytical Chemistry

Godefroid-Charles Blas (1839–1919), was born in Freiburg-im-Breisgau, Germany, and studied Pharma-

Fig. 12. Portrait of Charles Blas (1839–1919)

cy at the University of Giessen and then for the Doctor of Natural Sciences in the school of Liebig (for portrait see Fig. 12). In 1866 he was invited by the University of Louvain to deal with the reorganisation and new courses for pharmacists in the final year of their specialisation including that on the theory and practice of chemical analysis [105–107]. He is considered to be the founder of the School of Pharmacy at Louvain. During his career at Louvain (1866–1912) he taught almost all the courses in the pharmacy curriculum but analytical chemistry was his favourite discipline. In 1868 he created the first specialised laboratory for analytical chemistry in Belgium. When Blas arrived in Louvain from Germany he had little knowledge of French, however with his strong will and nature he soon became fluent in both its oral and written forms. His excellent teaching, well regarded text books and wide ranging expertise made him one of the important pioneers of analytical chemistry in Belgium.

Blas was a prolific writer of text books on pharmacy and on analytical chemistry. One of the more important of these was his 3 volume, *Traité de chimie analytique*, (1879–1886) [108] which was revised and reprinted 5 times, the last edition being in 1912 [109]. In 1881 he published an early monograph on the applications of electrolysis in chemical analysis [110]. Blas with his assistant Edouard Van Melckebeke (1843–1915) made an important contribution to the analysis and specifications for potable waters by their extensive report made for the 6th International Congress of Pharmacy, held in Brussels in 1885 on the quality of drinking water [111]. They discussed the various methods available for the determination of the chemical composition, microscopic and bacteriological examinations and the normal levels and maximal acceptable levels of substances.

After naturalisation in 1882 Blas was elected a Member of the Belgian Royal Academy of Medicine, and in 1889 a member of the High Commission on Hygiene. In addition to his analytical researches Blas made contributions to pharmacognosy and to natural product chemistry.

Following the retirement of Blas in 1912, the chair of analytical chemistry in the Faculties of Medicine and Sciences and in the Special School for Engineers was held by Pierre Bruylants (1885–1950), a son of the professor of food chemistry Gustave Bruylants (1850–1925) till 1919. He took charge of additional courses including that of organic chemistry. From 1920 his research became oriented to organic chemistry and he became responsible for the research at the photoproducts firm Gevaert.

(ii) Period of Modern Analytical Chemistry

Louis Michiels (1886–1936), was born in Louvain and obtained his Diploma in Pharmacy in 1908, in 1911 he became Doctor of Natural Sciences (chemical orientation), both degrees were obtained at the University of Louvain [112] (for portrait see Fig. 13). As he was interested in the new techniques of electrochemical and radiochemical analyses he went first to Aachen to study in the laboratory of Alexander Classen (1843–1934), the pioneer of electrochemical methods of analysis, then to Paris to study with J. Danne (1882–1919) and finally to Wiesbaden at the laboratory of Karl Fresenius (1818–1897), the doyen of classical analytical chemistry. He then returned to Louvain and was appointed in 1919 to teach the course in analytical chemistry, a year later he took over the course on toxicology. In support of his teaching he produced text books, several on analytical chemistry [113] and one on chemical toxicology [114]. As one of the last students of Louis Henri (1834–1913) it was not surprising he published some

Fig. 13. Portrait of Louis Michiels (1886–1936)

articles on pure organic chemistry, these skills in organic chemistry were invaluable in his researches for selective reagents for cations. Due to weak health he died quite young at 49 years of age.

Raymond Breckpot (1902–1983) obtained his doctor of sciences (chemistry) in 1923 for organic syntheses in the laboratory of P. Bruylants. In 1926 Breckpot was appointed to teach analytical chemistry in the Faculty of Applied Sciences and in the High School of Agronomy. In 1936 he became the director of the laboratory previously headed by Louis Michiels. In 1939 he became a co-founder of the Flemish Chemical Society, its first Vice-President (1939–1943) and President from 1945 till 1949. From 1935 till his death in 1983 Breckpot was an authority in spectrographic analytical methods. He introduced his techniques in various metallurgical industries for the control of production processes. In 1946 he became director of the research laboratory for the non-ferrous metals industry at Hoboken (near Antwerp). Breckpot was an influential advocate for the direct cooperation between Industry and the Universities in Belgium. He was a productive researcher in several areas including that on pure materials used to produce semiconductors [115]. G. Smets (1915–1991) in his eulogy of Breckpot for the Academy stated he had supervised 96 Ph.D. students [116].

Adolph Van Tiggelen (1914–1969) became a colleague of Breckpot in 1944 when he was appointed to teach analytical chemistry (French regime). Van Tiggelen studied for his Ph.D. in the Louvain laboratory of Walter Mund (1982–1956), a radio-chemist. Although he taught analytical chemistry, his main research was on the kinetics of combustion reactions which made him world famous. His last major publication was *Oxydations et Combustions*, (1968) [117].

In the Faculty of Medicine for the analytical chemistry courses for pharmacists Louis Michiels had the following successors. In 1923, Armand Castille (1898–1973) who was the first professor in this section appointed for Flemish courses in analytical chemistry. Later he taught additional courses, in toxicology, pharmaceutical chemistry, food chemistry and his favourite, pharmacognosy. This latter reflected his research interests in the isolation of pharmaceutically active compounds from vegetables. Castille was succeeded for the analytical courses in 1925 by Paul Putzeys (1897–1993) who also taught medicinal chemistry. Putzeys researched in the biochemical areas of the determination of the molecular weights of proteins and on their ionisation. René Lontie (1920–2000) followed Putzeys for the analytical chemistry courses, he also had research interests in biochemical topics.

The University of Brussels

The course on analytical chemistry started at the Faculty of Sciences and the Faculty of Applied Sciences in 1873 and from 1880 for the training of pharmacists. The first professor appointed in the discipline was Arthur Joly (1841–1911). In 1907 Adolphe Van Engelen (1861–1921), a doctor of sciences of the university of Brussels succeeded Joly for the training of pharmacists, doctors in sciences and engineers. Neither Joly nor Van Engelen left records of analytical research; however the later was active in the food section of the Belgian Association for Chemists.

After the death of Van Engelen the analytical chemistry course was taught by Alexander Pinkus (1891–1945). Pinkus was also appointed as professor of physical chemistry and researched mainly on the kinetics and mechanisms of chemical reactions. After Pinkus' death in a concentration camp at the end of the Second World War he was succeeded by Lucia de Brouckère (1904–1982). She was the first female professor of analytical chemistry in Belgium, and like Pinkus, had research interests mainly in physical chemistry.

In the Faculty of Medicine A Van Engelen was succeeded by Léon Herlant (1873–1968) until 1936 when Louis Maricq (1901–1984) took over. Maricq researched on electrochemical methods and on gas chromatographic procedures for the determination of alcohol in blood and the analysis of drugs.

Léopold Molle (1921) a pharmacist, qualified at the University of Brussels, a co-worker of Maricq, was in 1970 appointed director of the laboratory of analytical chemistry, inorganic pharmaceutical chemistry and toxicology. Molle, with his co-workers J. Nève, G. Patriarche and M. Hanocq, researched in several analytical areas but specialised in the separation and determination of trace elements. His best known work is on the optimisation of the wet-digestion of biological materials for mineralization of selenium [118] and its determination by graphite furnace atomisation atomic absorption spectrometry [119]. By the time of his retirement in 1986 he had published over 130 original research papers. Molle was succeeded by Michael Hanocq (1939) and Gaston

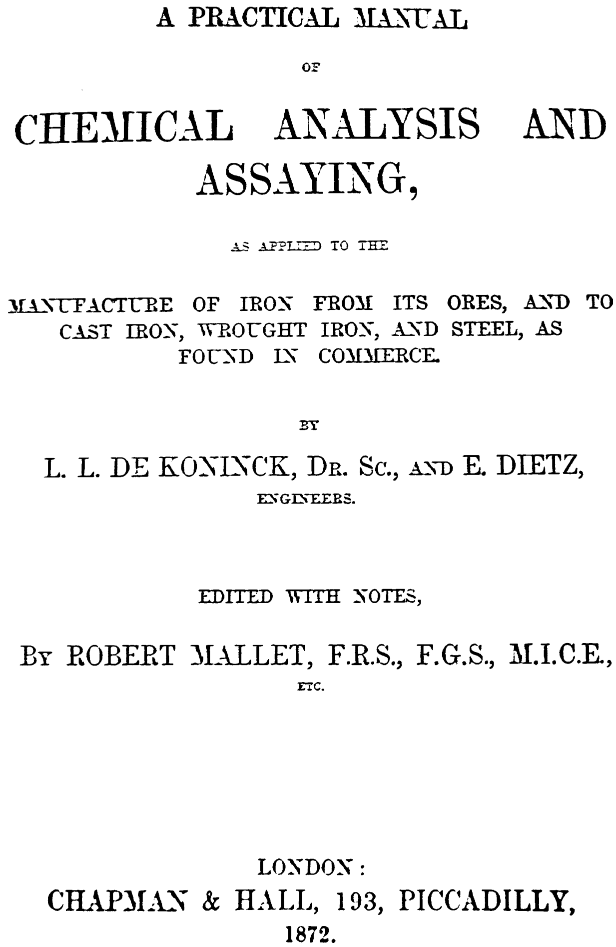
Patriarche (1930–1991) In 2001 both were succeeded by Jacques Dubois (1958) and Jean Michel Kauffmann (1954).

The University of Liège

(i) Classical Analytical Chemistry

Lucien Louis De Koninck (1844–1921), son of Laurent-Guillaume De Koninck, was born in Liège and attended his local University and graduated in engineering in 1867 [120] (for portrait see Fig. 14). In 1868 he went to Heidelberg and worked in Bunsen's laboratory and then to Bonn, where under the direction of Kekulé obtained his Doctorate in Natural Sciences on an organic topic.

On return to Liège he was appointed as assistant chemist in his father's Laboratory of Organic Chemistry. Here he wrote, with his friend E. Dietz, who was working in industry, *A Practical Manual of Chemical Analysis and Assaying . . .*, published in 1871 in French [121], in English 1872 [122] (see Fig. 15 for the title page of the English edition), reprinted in America 1873 [123]. That in French ran to 5 editions [124]. The authors noted in their preface, ''we have not met with a single treatise on the docimacy of iron in an exclusively industrial point of view. We have tried to supply this want''. In 1871 he returned to Germany and worked with H. Landolt (1831–1910) in Aachen for one year. Afterwards he became chemist in a glassworks in Charleroi until 1876.



A PRACTICAL MANUAL

OF

CHEMICAL ANALYSIS AND ASSAYING,

AS APPLIED TO THE

MANUFACTURE OF IRON FROM ITS ORES, AND TO CAST IRON, WROUGHT IRON, AND STEEL, AS FOUND IN COMMERCE.

BY

L. L. DE KONINCK, DR. SC., AND E. DIETZ,

ENGINEERS.

EDITED WITH NOTES,

BY ROBERT MALLET, F.R.S., F.G.S., M.I.C.E.,

ETC.

LONDON:

CHAPMAN & HALL, 193, PICCADILLY,

1872.

Fig. 15. Title page of De Koninck's *A Practical Manual of Chemical Analysis and Assaying*. (1872) [119]

Fig. 14. Portrait of Lucien Louis De Koninck (1844–1921)

In 1876 L. L. De Koninck was appointed Professor at Liège to teach the newly created course of analytical chemistry for students of pharmacy which was also available to students in the last year of their degree of Doctor of Natural Sciences. In 1879 he took over from I. Kupfferslaeger (1819–1890) the course on docimacy, that is analytical chemistry as applied to the metallurgical industry, specifically given for engineering students for which De Koninck established a special training laboratory. This course was given in the Special ("High") School for Engineering. He produced two undergraduate texts [125, 126] and a two volume, well illustrated, monograph on the analytical chemistry as applied to minerals (1894) [127] covering classical methods and, for the period, a wide range of physical methods of analysis such as electrogravimetry, polarimetry and colorimetry. In the preface he noted this treatise was the result of 17 years research. It ran to 5 French and 2 German editions, increased in from the second French edition to four volumes [120]. In addition to his text books De Koninck published over 200 research papers [128], including from 1896 a considerable number in *Bull Soc Chim Belge* [119]

After the retirement of L. L. De Koninck separate chairs of analytical chemistry were established, one in the Faculty of Sciences, the other specifically concerned with courses for pharmacists, in the Faculty of Medicine.

(ii) Modern Analytical Chemistry

(a) Faculty of Sciences

Maurice Huybrechts (1877–1950), studied pharmacy at the University of Brussels and graduated in 1900 and then at the University of Berlin where he became Doctor of Natural Sciences in 1902 [129]. That year he was appointed assistant in De Koninck's laboratory in Liège. In 1919 he was appointed Professor of Analytical Chemistry in the Faculty of Sciences and the Faculty of Technology. He published a series of text books, first in collaboration with L. L. De Koninck [130] and after De Koninck's death revised his *Manipulation*, to produce the 6th and the 7th Editions [131]. His research interests were mainly in metallurgical topics, he published much less than his predecessor.

Georges Duyckaerts (1911–1993), graduated in engineering in 1936 and then became Doctor in Applied Sciences in 1941, at the University of Liège [96b] (for portrait see Fig. 16). He was appointed Professor of Analytical Chemistry in the Faculty of Sciences in 1945. His research focussed on instrumental analytical methods initially in quantitative molecular spectroscopy and electroanalysis and then in nuclear chemistry. He was responsible for the introduction of new and up to date infrared and Raman spectrometers in Liège. His first research in nuclear chemistry concerned the separation of rare earths by liquid–liquid extraction and by ion-exchange, followed by the separation of uranium fission products. From 1956 his interests turned to the actinide elements,

Fig. 16. Portrait of Georges Duykaerts (1911–1993)

using the techniques of X-ray diffraction and mass spectrometry. Duyckaerts and his laboratory achieved an international reputation and attracted research and post-doctoral students worldwide. He retired in 1981 and was succeded in the Chair by Bernard Gilbert.

(b) Faculty of Medicine

François Schoofs (1875–1959), studied at the University of Liège and graduated in Pharmacy in 1898, then Medicine, graduating in 1903 [132] (for portrait see Fig. 17). He then specialised in hygiene, first in Hamburg, then in Liège under Professor F. Putzeys (1847–1932) and was awarded a special doctorate in physical and chemical sciences applied to hygiene in 1912. He was attached to the University of Liège from 1899 becoming Professor in 1913 to teach analytical chemistry, toxicology and legislation to intending pharmacists and students of industrial and colonial hygiene in the Faculty of Technology. Later, he taught food chemistry and toxicology, from 1920 and 1921 respectively. His analytical publications were on toxicology including a very early hyphenated method, electrochromatography [133], which predated by almost a decade the studies of Kemula on chromato-

Fig. 17. Portrait of François Schoofs (1875–1959)

polarography [134] and on pharmaceutical products and water.

Robert Chandelle (1893–1959), studied pharmacy at Liège and graduated in 1921 and was immediately appointed as an assistant to Prof. M. Huybrechts [135]. His research was into fundamental aspects of analytical chemistry in addition he published several textbooks. After the retirement of Prof. F. Schoofs in 1945 he was appointed to the Chair. After Chandelle's death in 1959, Charles Lapierre was appointed to follow him in the Chair.

The University of Ghent

(i) Classical Analytical Chemistry

During the classical period of analytical chemistry there were no prominent Professors of Analytical Chemistry in the University of Ghent. In the Faculty of Medicine the first person charged with the teaching of analytical chemistry to pharmacists was Theodoor Swarts (1839–1911) who was the successor of A. Kekulé. Swarts was followed from 1877 until 1892 by Edouard Dubois (1842–1892) who was also appointed as the first Professor of Analytical Chemistry in the Faculty of Sciences. Dubois published very little due to the heavy burden of teaching for two Faculties and his very premature death.

Maurice Delacre (1892–1938) followed Dubois from 1892 until 1895. Delacre obtained his doctorate at Louvain working in the laboratory of Louis Henri (1834–1913). Henri was the first world famous organic chemist in Belgium. Delacre was appointed to the Chair of Analytical Chemistry not only in the Faculty of Medicine, of Sciences but also in the Faculty of Applied Sciences. He was not interested in analytical chemistry and continued research in organic chemistry, at which he was very successful and as a result, at the turn of the century, was the best known organic chemist at Ghent.

Delacre was followed from 1895 until 1908 by Eugène Gilson (1862–1908) who died very young at 46 years old. His research was in pharmacognosy and in active substances in natural products. Gilson was followed from 1908 until 1914 by Louis Gesché (1870–1937). He was mainly concerned with the professional interests of pharmacists in Belgium and did no research in analytical chemistry.

Delacre was the only Professor for Analytical Chemistry in the three faculties from 1892 to 1895. In 1895 till 1898 the analytical courses were given in the Faculty of Applied Sciences by Jean Diomède Rottier (1833–1917). He retired in 1898 without producing any publications in the field. Rottier was followed till 1923 by William de la Royère (1856–1924) who likewise published no research in analytical chemistry.

(ii) Modern Analytical Chemistry

Johannes (Jan) Baptista Gillis (1893–1978) (for his portrait see Fig. 18). Jan Gillis was one of the most outstanding exponents of his generation in the field of modern analytical chemistry, he was also extremely important for his many other contributions to Belgian science [136–139]. He received his chemical training under the supervision of F. Swarts (1866–1940), the pioneer of the chemistry of organic fluorine compounds. During the First World War, Gillis was wounded and evacuated to The Netherlands. He then started his research career studying the thiocyanate-isothiocyanate equilibrium in the laboratory of A. Smits (1870–1948) at the State University of Amsterdam. In 1918 he underwent his Doctoral examination be-

Fig. 18. Portrait of Johannes Baptiste Gillis (1893–1978)

fore the Central Jury, set up by the Belgian authorities in Le Havre, France.

After the Armistice in 1918, Gillis was given an appointment in the laboratory of general chemistry of F. Swarts. Meanwhile he obtained a second Doctorate in botanical science in 1922. Gillis was one of the first Professors to be appointed at the start of the introduction of the Flemish linguistic regime at Ghent. He was appointed to the independent chair of analytical chemistry in 1923; his duties were extended to cover the Faculty of Applied Science the same year and to the Faculty of Medicine in 1925 to cover the mandatory training of pharmacists in analytical chemistry.

Gillis was an enthusiastic and efficient teacher, worked hard to reorganise and update his laboratories. Following his early training in physical chemistry he was one of the first in Belgium to introduce a rigorous theoretical approach in analytical chemistry including graphical representation of the mathematical functions relating the mass of a substance to the measured magnitude of appropriate physical or chemical properties [140]. He made valuable research contributions to potentiometry and rapid electroanalysis. Only a few years after J. Heyrovsky (1890–1967) had devised the first polarograph, he and B. J. Cuvelier (1905–1978) introduced this technique to Ghent [141]. With J. Eeckhout (1909–2001) he published numerous papers on the quantitative aspects of arc emission spectroscopy [142]. In 1940 Gillis was appointed to the International Committee on New Analytical Reactions and Reagents of the International Union for Pure and Applied Chemistry (IUPAC). He embarked on an extensive programme studying critically new organic reagents and reactions for inorganic analysis together with J. Hoste (1921), A. Claeys (1924–2001), J. Pijck (1930–1994) and others. In 1945 and in 1948, J. Gillis along with C. J. Nieuwenburg (1889–1985) (Delft, The Netherlands) and P. Wenger (1888–1962) (Geneva, Switzerland) produced the well-known IUPAC Reports *Reagents for Qualitative Inorganic Analysis* [143, 144]. With J. Eeckhout he devised a procedure to solve the difficult problem of the separation of niobium and tantalum [145]. From 1958 Gillis was involved in the application of radioactive tracers for the detection of compounds of biological origin [146]. Only a few of Jan Gillis' fields of research have been discussed, selected to demonstrate his outstanding abilities. In 1947 he was a co-founder of the well-known journal *Analytica Chimica Acta.* The School of Analytical Chemistry he founded continues to flourish, many of his former students and co-workers have gone on to become Professors in Analytical Chemistry (J. Eeckhout, J. Hoste and A. Claeys), others in Applied Chemistry (B. J. Cuvelier and J. Pijck).

In addition to his teaching and research he served the University of Ghent with great skill in a series of administrative roles, in the Faculty of Sciences, on the Board of the University and from 1953–1957 as Rector. In this later role, during a speech, in 1957, in Antwerp he stated it was necessary to extend the number of Universities in Belgium, thus he gave an important impulse towards the foundation of the University of Antwerp. In 1939 he made a significant input to the chemical profession in Belgium by being one of the founders of the Flemish Chemical Society (from 1989, The Royal Flemish Chemical Society, KVCV) and was its first President (1939–1943). After his retirement Gillis became very active in the field of the history of chemistry, making detailed studies of George Sarton [147], Leo Baekeland [149] and especially August Kekulé [149]

Joel (Zoël) Eeckhout (1909–2001), graduated in chemical engineering at the University of Ghent in

1940 and was appointed lecturer in analytical chemistry in 1949 [150]. However, after the retirement of R. Goubau (1886–1976) in 1957, he changed over to teaching general and some inorganic chemistry. His main research areas were in arc emission spectrography applied to metallurgical products and by-products, separation and determination of chemically similar pairs of ions (Nb/Ta, Ca/Sr) and neutron activation analysis.

Julien Hoste (1921), graduated Doctor of Sciences in Chemistry at the University of Ghent in 1947; he became an academic staff member in 1946 and lecturer in analytical chemistry in the Faculties of Sciences and in Applied Sciences in 1958 [151] (for portrait see Fig. 19). His early research was on sensitive and selective spectrophotometric reagents for a variety of elements. In 1958 with J. Gillis and J. Pijck he started radiochemical research. With the advent of intense neutron sources from the nuclear reactor at Mol a whole range of artificial isotopes became available and neutron activation analysis became his main field of interest [152]. In 1965 a new complex for analytical chemistry was established which included its own nuclear reactor. Hoste built up a world wide reputation in analytical radio-chemistry, from his a large output of research papers and eight high level monographs on neutron activation analysis. In 1972 he was awarded the "George Hevesy Medal". By the time of his retirement in 1986 he had over 450 papers to his credit and had supervised 73 Ph.D. candidates. He was succeeded in the Chair by Richard Dams (1938). The present holder of the chair is Luc Moens (1954) who is also currently the Vice-Rector of the University of Ghent.

Fig. 19. Portait of Julien Hoste (1921)

Frans Verbeek (1929), obtained his Doctor of Sciences (Chemistry) in 1957 at the University of Ghent. From 1961 to 1974 he was an Associate Professor under J. Hoste. His research focussed on electrochemical methods, especially advanced polarographic techniques and on atomic absorption spectrometry. He supervised 40 Ph.D. candidates and published over 140 papers.

Post the 1965 University Expansion Bills

In 1965 the Belgian Government passed the first University Expansion Bill. Two new state Universities were created; one in Antwerp the other in Mons, and also two Catholic High Schools; one in Antwerp the other in Namur. New Universities were also created in Hasselt and Kortrijk. In 1969 the French speaking Free University of Brussels formed the Flemish Free University in Brussels, and Louvain created a French speaking University which was placed in the newly created city of Louvain-la-Neuve.

This major expansion of Universities offered numerous possibilities to young scientists seeking their first academic posts as well as for those seeking promotions. The School of Analytical Chemistry at Ghent, headed by Hoste and Verbeek, has been particularly influential, of the 100 or so Ph.D.'s they produced 23 achieved Chairs; at Ghent (R. Dams, R. Cornelis, J. Op de Beeck, H. Thun, E. Temmerman, W. Ooghe, W. Maenhaut, L. Moens and K. Strijckmans), Flemish University of Brussels (D. L. Massart, F. De Corte and P. Van de Winkel), Hasselt (J.-P. François), Leuven (J. Hertogen, C. Vandecasteele, C. Block and M. J. Janssens) and to Antwerp (F. Adams, R. Gijbels, R. Van Grieken, R. Dewolfs, A. Lagrou and H. Deelstra).

Conclusions

The origin of analytical chemistry in Belgium can be traced back to the 17th Century iatrochemist J. B. Van Helmont, who was one of the first chemists using a balance in his researches. Attention has been drawn to the work of Jean Baptiste Van Mons, who in the late 18th and the early 19th Centuries, was a significant influence in the demise of the phlogiston theory and the dissemination of the new concepts in chemistry. He can be considered as the father of modern chemistry in Belgium. The assiduous work of J. S. Stas on the accurate determination of atomic weights meant that he was probably the most skilful analytical chemist of the 19th Century.

1876 was an important year for analytical chemistry in Belgium, because due to new State regulations for the training of pharmacists, the four Universities introduced new and compulsory courses in the subject. At the same time there existed an urgent need for applications of analytical chemistry in a range of industrial and public sectors. This situation led to the establishment, in 1887, of the Belgian Association of Chemists, which brought together the ''practising analytical chemists'' from the sugar industry, agriculture and public control of food, water etc. This Association organised in 1894 the International Congress on Applied Chemistry in Antwerp/Brussels.

During the classical period of analytical chemistry (1876–1914) the most eminent Professors of Analytical Chemistry in Belgium were C. Blas at Louvain and L. L. De Koninck at Liège. The modern period of analytical chemistry, considered to start post World War One, shows a continuation of the well known analytical laboratory in Liège with Professors M. Huybrechts and G. Duykaerts and new centres at Brussels with Prof. L. Molle and that started at Ghent (with Flemish as the official language) with Prof. J. Gillis, in a brand new centre for analytical chemistry, followed by J. Eeckhout and J. Hoste.

The emphasis of the course contents shifted from qualitative to more quantitative aspects, inorganic and organic applications to almost exclusively inorganic applications, during the time from the classical to the more modern period. During the modern period the classical techniques such as gasometry, titrimetry and gravimetry and some instrumental methods such as densitometry, refractometry, polarimetry and electrolysis were almost completely replaced by chromatographic, spectroscopic and other instrumental methods. It is also apparent that during the classical period the publication of good text books by academics was more highly regarded by the academic authorities than was the publication of separate research articles. In the modern period this position has been reversed and the publication of research papers in international, as opposed to national, journals has become more and more important for academics in Belgium, as in the rest of Europe.

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